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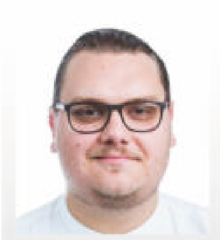
"Wrap your head around a mind-boggling fact: objects can be in two places at once"

Quantum computers, page 22

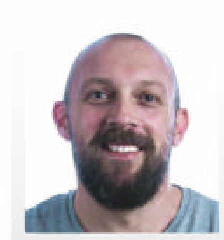
Meet the team...

Nikole
Production Editor
Explore the space oddities of our Solar System – methane lakes, gushing geysers and Martian mountains can be found on page 70.



Scott
Staff Writer
Meet the animals dressed in armour to fight off foes and, in some cases, turn predators into pincushions on page 42.

Baljeet
Research Editor
All aboard the floating labratory that is using ocean sediments to look back in time and unlock the history of Earth on page 52.



Duncan
Senior Art Editor
What will the weapons of the future look like? Turn to page 36 for a glimpse into the next developments in human warfare.

Ailsa
Staff Writer
From blood-sucking leeches to pain-killing cocaine, check out the crazy medicines used in Victorian healthcare on page 66.

I'm old enough to remember the IBM personal computer my dad used for his work, equipped with a processor capable of a whopping 4.77 million calculations per second. Sounds like a lot, doesn't it? Today's personal computers have multi-core gigahertz processors over 1,000 times faster than that early computer system, and modern supercomputers are millions of times faster than today's PCs again. To think that quantum computers have the potential to solve currently impossible problems in medicine, AI and more, and outperform supercomputers by several orders of magnitude, is incredible. Read more on page 22.

Ben Editor

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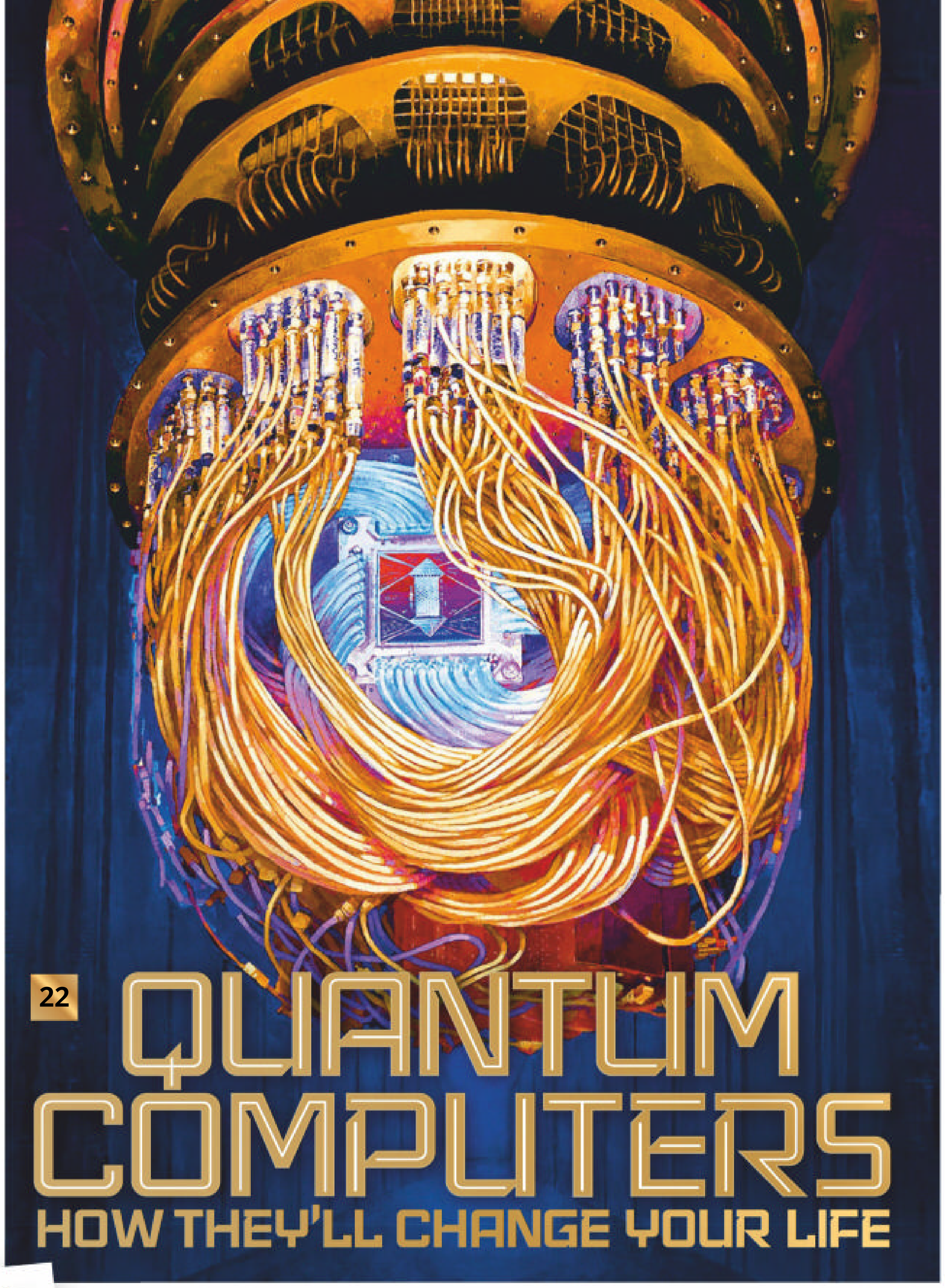

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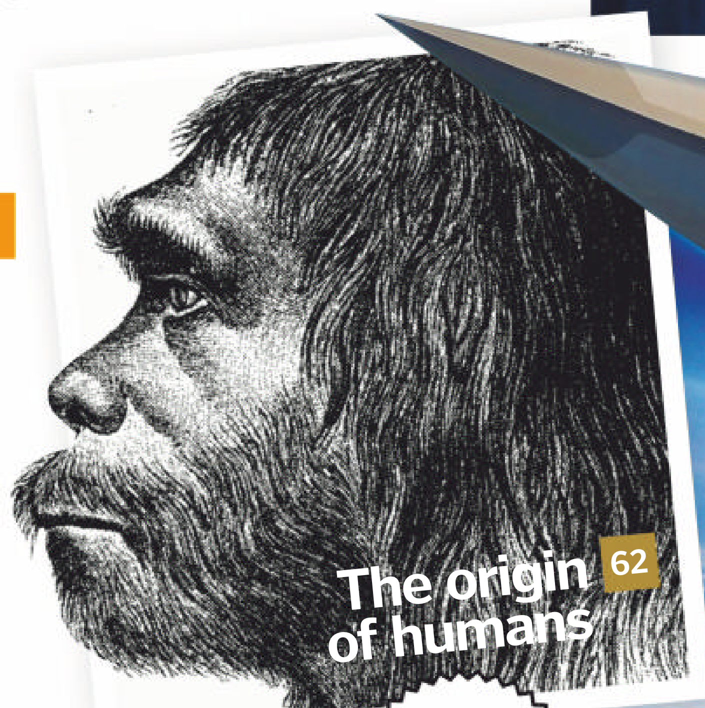

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AR ZONE!

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AR ZONE!

NEW

Download a free QR code reader app for your mobile phone if your phone hasn't got one –many iPhone and Android models have

When you see the AR ZONE! logo at the top of a page, use your phone to scan the QR code, which looks like this

Hold your mobile device over the image and watch it come to life! Your device needs to be connected to the internet for this to work

HOW THE AUGMENTED REALITY WORKS

After being launched by the QR code, the app reads anything you point your device's camera at 30 times a second, searching for distinctive shapes we've trained it to recognise. When it sees a familiar picture, it overlays the augmented reality 3D image we've previously uploaded on your screen.

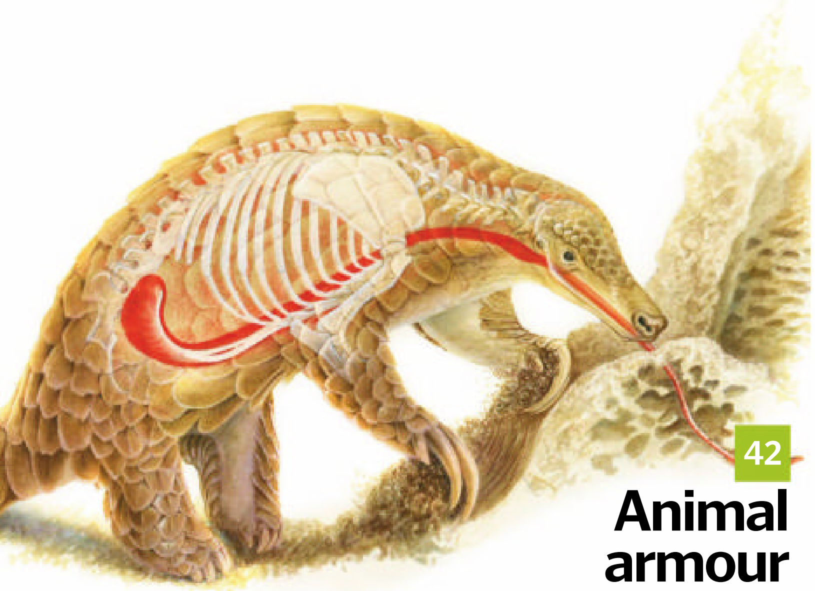
MEET THIS ISSUE'S EXPERTS...

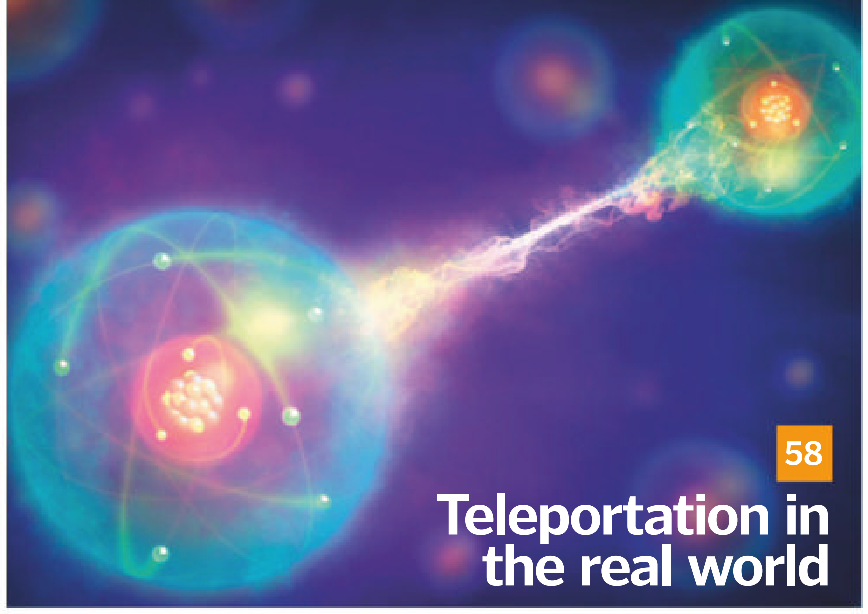
Jo Elphick
Jo is an academic lawyer and lecturer specialising in criminal law and forensics. She is also the author of a number of true crime books.

Mark Smith
A technology and multimedia specialist, Mark has written tech articles for leading online and print publications for many years.

Andy Extance
Andy is a freelance science writer based in Exeter, UK. He previously worked in early stage drug discovery research, followed by a brief stint in silicone adhesive and rubber manufacturing.

Dr Andrew May
Andrew has a PhD in astrophysics and 30 years in public and private industry. He enjoys space writing and is the author of several books.





AR ZONE!

AR ZONE!

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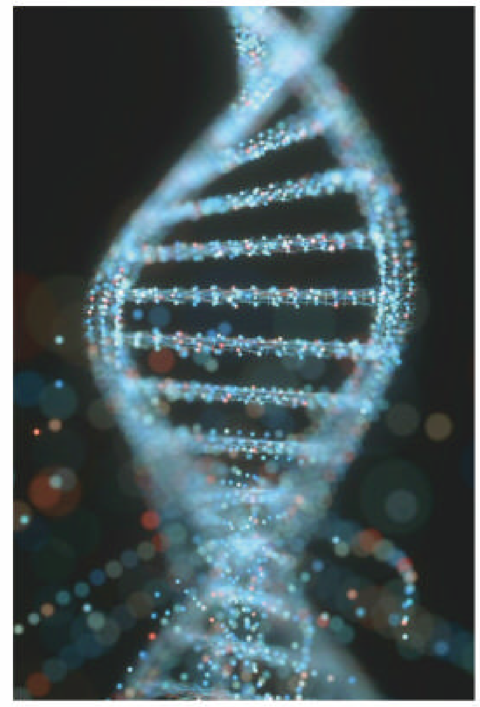
REGULARS



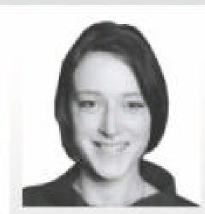
© Getty

Amy Grisdale
Volunteer animal worker Amy has an enormous breadth of experience on animal conservation projects. She specialises in writing about environmental topics.

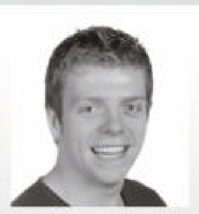
Steve Wright
Steve has worked as an editor on various publications. He particularly enjoys history feature writing and regularly writes literature and film reviews.

Stephen Ashby
Stephen is a writer and editor with video games and computer tech expertise. He is endlessly intrigued by Earth science.

Jack Parsons
A self-confessed technophile, Jack has a keen interest in gadgets and wearable tech, but also loves to write about tech projects with much grander ambitions.



Laura Mears
Biomedical scientist Laura escaped the lab to write about science and is now working towards her PhD in computational evolution.



Jonny O'Callaghan
With a background in astrophysics, former **HIW** and **All About Space** writer Jonny enjoys delving into the wonders of space and space missions.

Face cream gets a close-up

Although this might appear to have been crafted at the hands of a graphic designer, it is in fact the naturally occurring crystal film of a popular face cream. Smeared out on a cool surface and allowed to dry, stages of the chemical crystallisation result in this leafy tessellation. The array of intermingling colours is the result of a phenomenon called birefringence, whereby light is split into two components as it passes through the crystallisation. This tantalising tessellation was captured by Yevhen Samuchenko for The Royal Photographic Society's 2019 science photography competition. You can find out more about this year's entries at **rps.org/spoty**.


© Shutterstock

Fibre-optic nymphs

As their name suggests, planthopper nymphs spend their time leaping between leaves. Before reaching adulthood, planthopper nymphs (Ricaniidae) extrude a waxy material from their abdomen to create strands which can appear as natural fibre-optic spines. Acting as a visual warning to potential predators, the fanned waxy spindles at the rear also help planthopper nymphs glide between leaves. Less than five millimetres long, some species of planthopper nymphs, such as *Issus coleoptratus*, can jump up to a metre high in a single leap.

Up, up and away

On the full Moon of the 12th lunar month each year, people across northern Thailand gather to release amber-glowing lanterns into the sky. The Yi Peng festival (also written as Yee Peng) occurs around mid-November, with the majority of people gathering in the city of Chiang Mai to release lanterns. The tradition of sending lanterns into the sky symbolises letting go of misfortune, and it's said that wishes made upon their release will come true.

ANIMALS

Deep-sea stethoscope listens to a blue whale's heartbeat

Words by **Brandon Specktor**

When the largest animals on Earth grab a snack, their hearts skip a beat – or 30. That's what a team of marine biologists found after recording a blue whale's heartbeat for the first time ever. After suction-cupping a pulse monitor to the back of a blue whale off the California coast, the researchers watched as the gargantuan creature dove and resurfaced nonstop for nearly nine hours, alternately filling its lungs with air and its belly with schools of fish.

During these deep, grub-hunting dives, the whale's heart rate fluctuated wildly, pumping as many as 34 times per minute at the surface and as few as just two beats per minute at the deepest depths – about 30 to 50 per cent slower than the researchers expected.

According to a recent study, the simple act of catching a bite may push a blue whale's heart to its physical limits. "Animals that are operating at physiological extremes can help us understand biological limits to size," lead study author Jeremy Goldbogen, an assistant professor at Stanford University in California, said in a statement. This natural cardiac limit may explain why blue whales max out at a certain size, and why there have never been any known animals on Earth any larger. Because a bigger creature would require even more oxygen to sustain its long deep dives for sustenance, its heart would need to beat even faster than a blue whale's to refuel its body with oxygen at the surface.

According to the study authors, that doesn't seem possible based on the current data; blue whales may have – now and forever – the hardest-working hearts on Earth.

The world's largest animal can survive on just two heartbeats per minute

HEALTH

'Doughnut-shaped' DNA makes cancer more aggressive

Words by **Yasemin Saplakoglu**

Cancer cells may owe some of their destructive nature to unique, 'doughnut-shaped' DNA, according to a recent study. Published in the journal *Nature*, the study found that in some cancer cells, DNA doesn't pack into thread-like structures like it does in healthy cells – rather, the genetic material folds into a ring-like shape that makes the cancer more aggressive.

"DNA conveys information not only in its sequence, but also in its shape," said co-senior author Paul Mischel, a professor of pathology at the University of California at San Diego. As you may remember from biology class, most of our DNA is packed tightly inside cells' nuclei in structures known as chromosomes.

This jam-packed structure allows for some genes to be accessible by the molecules that 'read' and carry out the genetic instructions, while other genes stay hidden. What results is highly regulated machinery that keeps the cell from carrying out unwanted genetic instructions and from replicating – creating new 'daughter cells' – in an erratic way.

"Everything we've learned about genetics says that changes [in cells] should be slow," Mischel told **Live Science**. But years ago, Mischel and his team found that in a certain type of brain cancer called glioblastoma, tumours "seemed to be able to change at a rate that just didn't make any sense." The tumour cells, as they divided into daughter cells, seemed to be somehow amplifying the expression of oncogenes – genes that can transform a regular cell into a cancerous one.

It turned out that some of these amplified copies of oncogenes had "untethered themselves from chromosomes," Mischel said. Having broken loose from the chromosomes, they were hanging out on other pieces of DNA inside the cell. They then found that these 'extrachromosomal' pieces of DNA – ecDNA – actually occur in nearly half of human cancers but have rarely been detected in healthy cells.

In this recent study, they figured out why ecDNA is so robust. A combination of imaging and molecular analysis revealed that these pieces of DNA are wrapped around proteins in a ring shape, similar to the circular DNA found in bacteria. This ring shape makes it much easier for the cell's machinery to access a slew of genetic information – including the oncogenes – so that it can quickly transcribe and express them, for example, instruct a healthy cell to turn cancerous, Mischel said. This easy accessibility allows tumour cells to generate large amounts of tumour-promoting oncogenes, evolve quickly and adapt easily to a changing environment.

© Getty

DNA contains all the information that an organism needs to function

© Getty

In September 2019, Tesla co-founder and CEO Elon Musk teased that Tesla's new electric pickup truck would look 'futuristic-like' and 'cyberpunk'

TECH

Tesla Cybertruck's revolutionary retro look

Words by **Nicoletta Lanese**

No, you haven't been sucked into a low-res video game – the new Tesla Cybertruck just looks like an animated armoured vehicle whose pixels are taking a while to render.

When Elon Musk rolled out the Cybertruck in November 2019, the truck's strikingly angular design certainly caught peoples' eyes, but auto experts say the look has as much to do with function as form.

Unlike many pickup trucks, the Cybertruck has a unibody design, meaning the vehicle is built around a metal scaffolding, according to *TechCrunch*. In standard pickup trucks, the vehicle's body rests atop a metal frame that both supports the engine and absorbs physical stresses.

The Cybertruck boasts a maximum towing capacity of 6,350 kilograms and a payload of 1,580 kilograms, according to *Outside* magazine. Although powerful, the truck body remains lightweight thanks to its stainless-steel monocoque frame. The reduced weight enables the all-wheel-drive model to accelerate from 0 to 100 kilometres per hour in just 2.9 seconds, even though its battery alone weighs more than 450 kilograms.

The same stainless steel used for the Cybertruck encases SpaceX's Starship spacecraft, and Tesla claims the metal will resist dents, corrosion and even bullets. The truck's 'armoured-glass' windows proved less impressive, though. Tesla's chief designer, Franz von Holzhausen, chucked a steel ball at not one, but two windows during the unveiling event, shattering both. "It didn't go through, so that's a plus side," Musk said. "Room for improvement."

"Unlike many pickup trucks, the Cybertruck has a unibody design, meaning the vehicle is built around a metal scaffolding"

HISTORY

Viking bodies found buried between boats

Words by **Nicoletta Lanese**

Replicas of two historic Viking longboats at Lofoten Islands, Norway

© Shutterstock

When archaeologists excavated an unusual Viking grave site in Norway, they dug up two bodies… along with the remnants of two massive boats. After hundreds of years underground, only remnants of the wooden vessels remained, but the excavation team could tell the two had been stacked atop each other. Viking burial sites often feature boats, but boats buried inside each other are "essentially an unknown phenomenon," Raymond Sauvage, an archaeologist at the Norwegian University of Science and Technology (NTNU) University Museum, said in a statement. The boats' occupants only added to the mystery of the burial site.

The top boat, about seven to eight metres long, contained the remains of a woman surrounded by a collection of ornaments, including a pearl necklace, two pairs of scissors, part of a spindle and an entire cow head. The woman's remains were adorned with two shining brooches, one shell-shaped and one in the shape of a crucifix.

The crucifix "decoration and the design itself tell us that it came from Ireland, and that it was once part of a harness fitting," Aina Heen Pettersen, a researcher in the NTNU department of historical studies, said in the statement.

Vikings who took part in voyages and raids often collected harness fittings as jewellery, Pettersen added. Based on the goods recovered from the woman's grave, the archaeologists determined that she had died during the second half of the 9th century. But remarkably, the man whose body had been buried in the boat below died in the century prior, they discovered. The man's boat measured about nine to ten metres long and contained a shield, a spear and a single-edged sword. "Sword styles change through the centuries, which means we can unambiguously date this grave to the 8th century, the period that is known as the Merovingian era in Northern Europe," Sauvage said.

"That's assuming that we are not dealing with a Viking hipster," he added. Sauvage and his team concluded that upon the woman's death, Vikings had carefully excavated the man's boat, placed the smaller boat inside, and reburied both vessels together.

© Getty

The pork tapeworm, *Taenia solium*, is common in developing nations, including countries in Latin America, Africa and Asia

HEALTH

Hot-pot meat leaves man with brain parasite

Words by **Rachael Rettner**

A man in China ended up with tapeworm larvae in his brain after eating a hot-pot meal that was likely undercooked, according to news reports.

The 46-year-old man, who lives in the eastern province of Zhejiang, went to the hospital after developing neurological symptoms including headaches, dizziness and epilepsy-like episodes of limb twitching and foaming at the mouth.

Doctors at the First Affiliated Hospital of Zhejiang University School of Medicine performed an MRI, which showed he had multiple lesions in his brain. He was diagnosed with neurocysticercosis, a parasitic disease of the central nervous system that occurs when a person ingests microscopic eggs from a pork tapeworm (*Taenia solium*). When the eggs hatch, the larvae can travel throughout the body, including to the brain, muscles, skin and eyes, where they form cysts, according to the World Health Organization (WHO).

Doctors suspect that the man had purchased meat contaminated with tapeworm larvae, and that he didn't cook it well enough to kill those larvae, the *Post* reported.

The man received treatment to eliminate the tapeworms and reduce pressure in his brain, the *Post* reported, and he made a full recovery.

SPACE

Physicists simulate the origins of the universe

Words by **Tim Childers**

> "Galaxies we observe today arose from the fiery chaos of the Big Bang"

The formation of galaxies is a complex dance between matter and energy, occurring on a stage of cosmic proportions and spanning billions of years. How the diversity of structured and dynamic galaxies we observe today arose from the fiery chaos of the Big Bang remains one of the most difficult unsolved puzzles of cosmology.

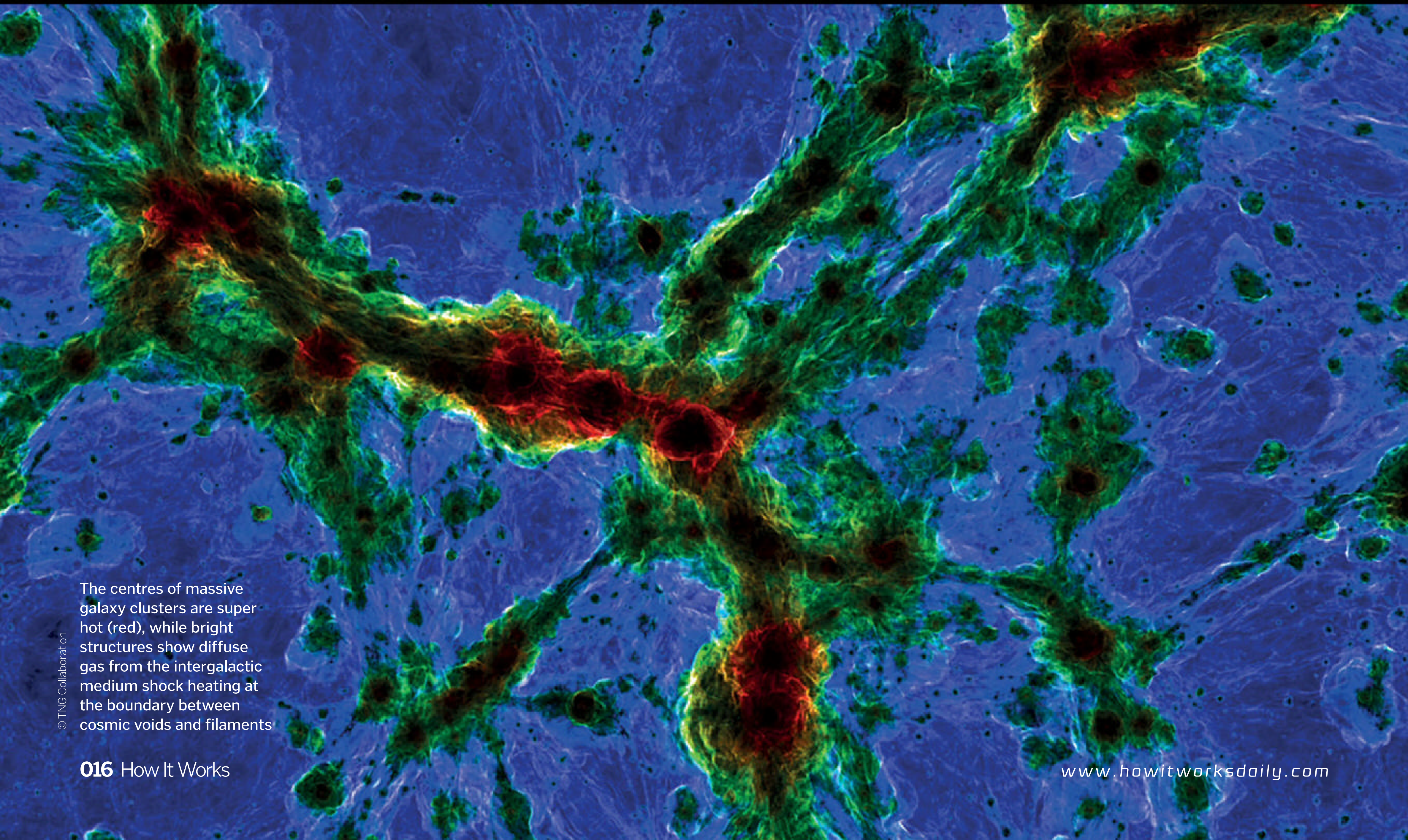
In search of answers, an international team of scientists has created the most detailed large-scale model of the universe to date, a simulation they call TNG50. Their virtual universe, some 230 million light years wide, contains tens of thousands of evolving galaxies with levels of detail previously seen only in single-galaxy models. The simulation tracked more than 20 billion particles representing dark matter, gases, stars and supermassive black holes over a 13.8-billion-year period.

The unprecedented resolution and scale allowed the researchers to gather key insights into our own universe's past, revealing how various oddly shaped galaxies morphed themselves into being and how stellar explosions and black holes triggered this galactic evolution.

TNG50 is the latest simulation created by the IllustrisTNG project, which aims to build a complete picture of how our universe evolved since the Big Bang by producing a large-scale universe without sacrificing the fine details of individual galaxies.

TNG50 has allowed researchers to see firsthand how galaxies may have emerged from the turbulent clouds of gas present shortly after the universe was born. They discovered that the disc-shaped galaxies common to our cosmic neighbourhood naturally emerged within their simulation and produced internal structures including spiral arms, bulges and bars extending from their central supermassive black holes. When they compared their computer-generated universe to real-life observations, they found their population of galaxies was qualitatively consistent with reality.

As their galaxies continued to flatten into well-ordered rotating discs, another phenomenon began to emerge. Supernovae explosions and supermassive black holes at the heart of each galaxy created high-speed outflows of gas. These outflows morphed into fountains of gas rising thousands of light years above a galaxy. The tug of gravity eventually brought much of this gas back into the galaxy's disc, redistributing it to its outer edge and creating a feedback loop of gas outflow and inflow. Apart from recycling the ingredients for forming new stars, the outflows were also shown to change their galaxy's structure. The recycled gases accelerated the transformation of galaxies into thin rotating discs – despite these initial findings, however, the team is far from finished dissecting their model.



The centres of massive galaxy clusters are super hot (red), while bright structures show diffuse gas from the intergalactic medium shock heating at the boundary between cosmic voids and filaments

Scientists named the ancient pup 'Dogor', which is 'friend' in the Yakut language

© Sergey Federov/The Siberian Times

HISTORY

18,000-year-old Siberian pup links wolves to dogs

Words by **Mindy Weisberger**

A young pup that spent 18,000 years buried in Siberian permafrost looks remarkably lifelike and pettable – for a freeze-dried mummy. The ice-age canine's body emerged from its frozen tomb in near-perfect condition, retaining even the pads and nails on its small feet and plenty of hair, down to its tiny eyelashes and delicate whiskers.

The pup still had its milk teeth, suggesting it was under two months old when it died. The body is so well preserved that its resemblance to a wolf is clearly visible, *The Siberian Times* recently reported. But is the youngster a wolf, or a dog? Dogs are descended from wolves, and their lineage may have split from their lupine ancestors' as early as 40,000 years ago, according to ancient DNA evidence.

Scientists at the University of Stockholm's Centre for Palaeogenetics conducted genetic tests on the Siberian pup's remains, but they were unable to determine if the mummy represented a dog or a wolf. Researchers discovered the mummified pup during the summer of 2018 near the Indigirka River in Yakutia, in the northeastern part of Russia.

The oldest known fossil of a domesticated dog dates from 14,700 years ago, though remains of dog-like canines are known from 35,000 years ago. A mummified canine dating from 18,000 years ago could be a dog, a wolf or possibly an animal with traits of both. "We can't wait to get results from further tests," Sergey Fedorov of the North-Eastern Federal University in Yakutsk, Russia, told the *Times*.

ANIMALS

Malaysia says goodbye to the last Sumatran rhino

Words by **Mindy Weisberger**

The last Sumatran rhino in Malaysia, a female dubbed 'Iman', died on 23 November at the Borneo Rhino Sanctuary in Sabah. Her death at age 25 marks the extinction of her species in that country and is a grim reminder of the animals' vulnerability; fewer than 80 wild Sumatran rhinos (*Dicerorhinus sumatrensis*) remain in the wild, according to the International Union for Conservation of Nature (IUCN). Captured in 2014 and brought to the sanctuary for a breeding programme, Iman suffered from uterine fibroid tumours – growths on the walls of her uterus – that sent her health into a serious decline over the past few years, Malaysian news site *Malaysiakini* reported. Recently, Iman's tumours were putting increasing pressure on her bladder and causing her significant pain, officials told *Malaysiakini*. The rhinoceros reportedly died from shock, said state tourism, culture and environment minister Datuk Christina Liew, according to Malaysian English-language news site *The Star*.

© Alamy

Sumatran rhinos are the smallest species, about one metre tall and weighing around 900 kilograms

The Nile River begins high up in the Ethiopian Highlands near the Blue Nile Falls shown here

PLANET EARTH

The Nile is much younger than we thought

Words by **Yasemin Saplakoglu**

For thousands of years the Nile River has fertilised valleys along its winding path through northeastern Africa, anchoring ancient civilisations and still serving as a route of transport and irrigation today.

But the age of its venerable waters, which stretch over 6,800 kilometres, has been debated, with one group of experts claiming the river was born around six million years ago when a drainage system changed course, while another claims the river is five times older than that.

A recent study finds evidence that supports the latter theory: the Nile River may have emerged around 30 million years ago, driven by the motion of Earth's mantle – the thick layer of rock between the Earth's core and crust.

The Nile River is thought to have formed at the same time as the Ethiopian Highlands, said lead author Claudio Faccenna, a professor at the Jackson School of Geosciences, University of Texas. The Ethiopian Highlands is where one of the Nile River's major tributaries, or branches, called the Blue Nile, begins.

"The Nile River may have emerged around 30 million years ago, driven by the motion of Earth's mantle"

The Blue Nile brings in the majority of the Nile River's water – and most of the sediments in it – joining with the river's other tributary, the White Nile, in Sudan before emptying out into the Mediterranean Sea.

Faccenna and his team had previously analysed sediments collected from the Nile Delta – land created as sediment is deposited where the river meets the Mediterranean – and compared their composition and age with ancient volcanic rock found on the Ethiopian plateau. They found that the sediments and rocks matched and were between 20 million and 30 million years old, suggesting the river formed at the same time as the plateau.

SPACE

Stellar black hole is 'too big to exist'

Words by **Yasemin Saplakoglu**

A gigantic stellar black hole 15,000 light years from Earth is twice as massive as what researchers thought was possible in our own galaxy.

The black hole is 70 times more massive than the Sun, the scientists wrote in a recent study. Previously scientists thought the mass of a stellar black hole, formed from the gravitational collapse of massive stars, couldn't exceed 30 times that of the Sun.

"We thought that very massive stars with the chemical composition typical of our galaxy must shed most of their gas in powerful stellar winds as they approach the end of their life," lead study author Jifeng Liu, deputy director-general of the Chinese Academy of Sciences' National Astronomical Observatories, said in a statement. "Therefore, they should not leave behind such a massive remnant."

It is thought that our Milky Way galaxy contains some 100 million stellar black holes, yet scientists have discovered only about two dozen of them, according to the statement. That's because until a couple of years ago, the only way scientists could discover these giant beasts was by detecting the X-rays they emitted while they chomped away at their stellar companions. But most black holes in our galaxy don't have much of an appetite and thus don't release X-rays, the researchers explained in the statement.

So Liu and his team turned to another method: they scanned the skies with China's Large Sky Area Multi-Object Fiber Spectroscopic Telescope. Using this telescope, they searched for stars that orbit seemingly invisible objects, held on tight by the object's gravity. That's how the researchers came across one star 15,000 light years away that was dancing around nothing – but was held in an orbit by something that could only be a black hole, they wrote.

The black hole "is twice as massive as what we thought possible," Liu said in the statement. "Now, theorists will have to take up the challenge of explaining its formation."

The black hole is more than twice the size that scientists thought possible

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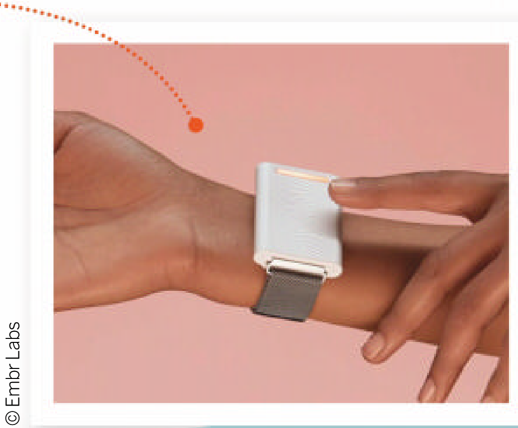
Embr Wave bracelet

■ Price: **From $299 (approx £230)**
embrlabs.com

Are you the one in the office or classroom always feeling the cold? If you need a smart way to keep warm, Embr Labs has created the Embr Wave, a wearable wrist warmer that releases thermal waves to bring you up to temp. Paired with your smartphone, control your perfect body temperature at the touch of a button. Not only a way to warm up, the Embr Wave can easily be switched to a cooler temperature during the warmer months.



© Embr Labs

Nanopresso

■ Price: **£50.90 / $64.90**
www.wacaco.com

Is there anything better than a freshly brewed coffee on a cold winter day? With the Nanopresso by Wacaco you can get a fresh brew on the go. Adding either ground coffee beans or a capsule and a cup of hot water, using the manual pump mechanism brews a steaming espresso every time.

© Wacaco

© KJUS

7SPHERE HYDRO_ BOT Jacket

■ Price: **£1,299 / $1,699** www.kjus.com

If you're hitting the slopes this winter season and you want to stay dry while you ski, then this high-tech jacket might be for you. As the first of its kind, the 7SPHERE jacket is equipped with HYDRO_BOT technology, which actively pumps out moisture from within. Using a process called electro-osmosis, tiny pores in the jacket's membrane pump out sweat when electrically stimulated, leaving your body dry.

WF-SP900 Sports Wireless Headphones

© Sony

■ Price: **£249 (approx $320)**
www.sony.co.uk

The WF-SP900 wireless headphones by Sony are a great way to listen to music while facing off with the winter weather. Bluetooth connected, these earbuds will fit snug under your woolly hat while providing around three hours of music streaming when fully charged. Waterproof – including saltwater – and dustproof, these durable earbuds also have a built-in 4GB onboard storage so you can save your music directly to playback for six hours when charged. The WF-SP900 come equipped with Ambient Sound Mode, which mixes your music with the sounds around you so you are always aware of your surroundings.

Digit touchscreen gloves

© Moshi

■ Price: **£29.95 (approx $40)**
www.moshi.com

Stay connected without freezing your fingers with these touchscreen gloves by Moshi. Using connective fibres on all ten fingertips, these gloves offer maximum manoeuvrability on your smartphone. Thanks to the GripTrak™ pattern on the palms of the gloves, your smartphone stays secure in your grasp. Machine washable, Digits boast a microfleece lining, keeping your hands cosy in the cold.

Zipfy

■ Price: **$44.95 (approx £35)**
www.zipfy.com

Sail down any snowy hillside with the Zipfy sledge, fun for the whole family. Zipfy is made with durable polyethylene plastic, capable of carrying a load of around 114 kilograms. With the Zipfy's feet-first design, riders can brake quickly and carve the slopes like a pro. Only weighing around 1.6 kilograms, this lightweight sledge will be a breeze to carry back up the hill for another ride.

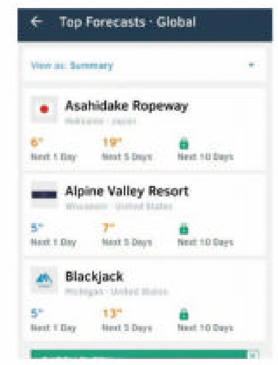
© Zipfy

APPS & GAMES

OpenSnow

■ Developer: **Cloudnine Weather LLC**
■ Price: **Free / Google Play / App Store**

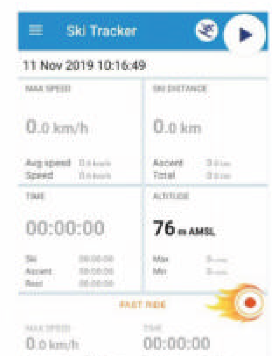
Stay up to date with the latest snow forecasts and live cams over 2,000 mountain ski destinations around the US, Canada, Japan and Europe.



Ski Tracker

■ Developer: **EXA Tools**
■ Price: **Free / Google Play**

If you love winter sports then this is the tracking app for you. Monitor your maximum skiing speed, distance and record your sloped on the apps map.



Winter Survival Kit

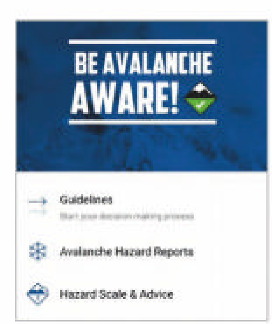
■ Developer: **NDSU Extension**
■ Price: **Free / Google Play / App Store**

If you find yourself stuck in the snow, this app might be able to help you out. It can find your location, call 911 and even offer advice on how long to run your engine to stay warm and safe.

Be Avalanche Aware

■ Developer: **Scottish Avalanche Information Service**
■ Price: **Free / Google Play / App Store**

Avalanches occur around the world, including the UK, and in particular the Scottish Highlands. This app offers daily avalanche reports, conditions and forecasts.



QUANT
COMPU

A new generation of number-crunchers are harnessing the power of particles: how will these super-fast computers change our world?

Words by **Jack Parsons**

Google says it has accomplished 'quantum supremacy'. This is a fancy way of saying its Sycamore processor can do something unique. It worked out a complex maths problem in three minutes and 20 seconds. The search-engine giant says a state-of-the-art supercomputer would struggle to do it in under 10,000 years. This is because Sycamore isn't just an upgrade on existing technology… it's a completely different way of working.

Sycamore is a quantum computer, meaning it's supercharged by the strange behaviour of particles. This advanced processing power could help cure dementia or invent artificial intelligence, so it's no surprise other tech firms are hard at work developing their own versions. Even governments are investing billions into their own research. In fact, the rivalry between the United States and China has been called the '21st-century Space Race'.

While Sycamore is a giant leap for Google, it's only the first step for this tech revolution. The underlying physics that make quantum computing so extraordinary also cause some of its biggest challenges. And we haven't solved many of them yet.

To understand how quantum computers work, you need to wrap your head around a mind-boggling fact: objects can be in two places at once. This is very hard to grasp, in part because it's not how we perceive things, and also because for centuries Isaac Newton and other scientists have said the world follows predictable patterns. For instance, an apple always falls down to the ground, even if it bonks you on the head first. And if you take that apple home and put it in your kitchen, you're not suddenly going to find it in your bathroom.

But these rules don't apply at the subatomic level. This is what 'quantum' means: the smallest amount – or quantity – we can measure, the building blocks of the universe. In the early 20th century, scientists like Niels Bohr, Werner Heisenberg and Erwin Schrödinger found that though particles can be found almost anywhere, the certainty of finding one in any particular place is zero. This is because particles can be in two places at once. For instance, electrons spin both up and down simultaneously.

Physicists call this behaviour 'superposition'. To complicate matters, superposition only happens when we're not looking. The moment we try and measure it, the particles lose their uncertain state and only spin up or down. The best physicists can do is work out the chance of which state they will appear in when observed.

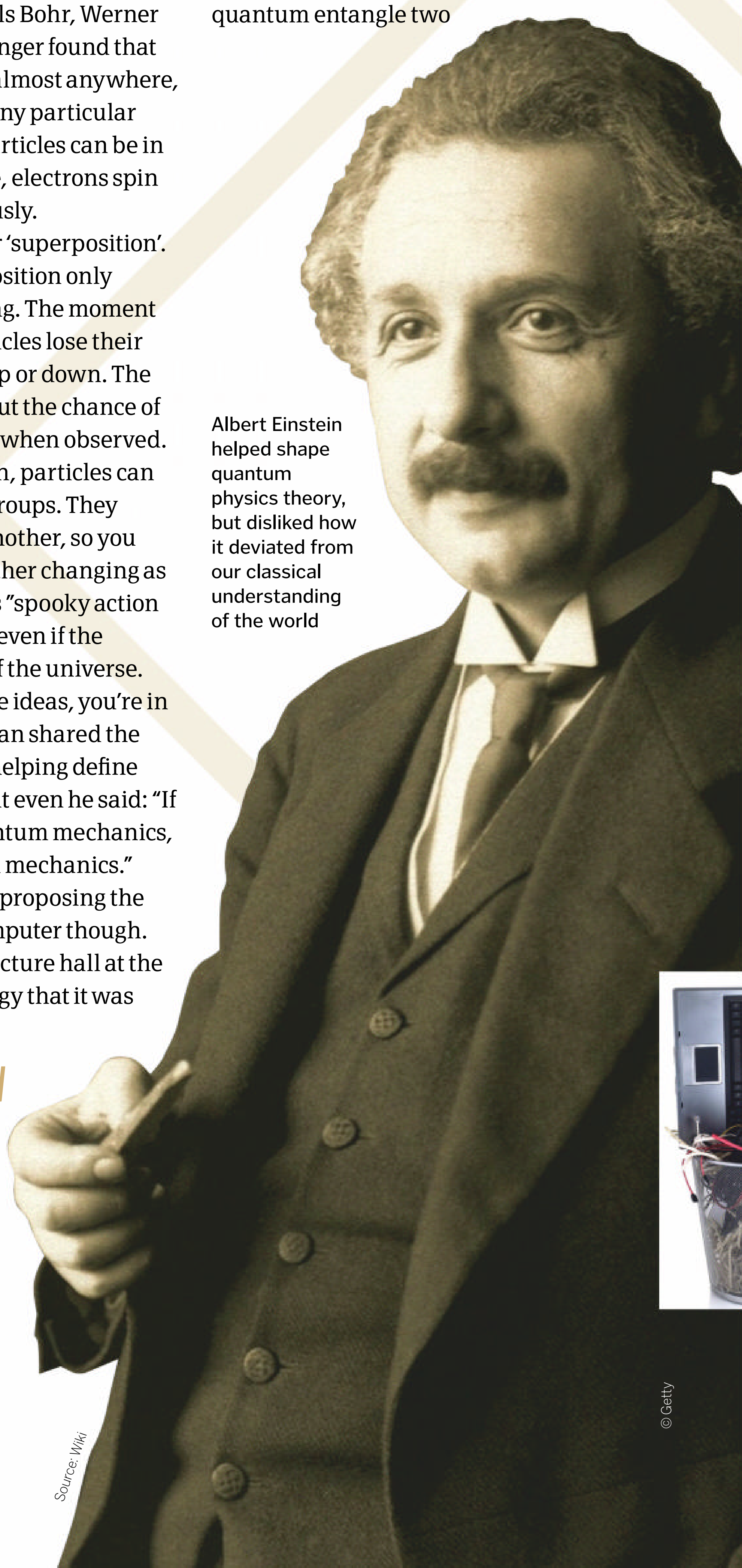
As if this wasn't weird enough, particles can also be 'entangled' in pairs or groups. They become deeply linked to one another, so you can't change one without the other changing as well. Albert Einstein called this "spooky action at a distance" because it works even if the particles are at opposite ends of the universe.

If you're struggling with these ideas, you're in good company. Richard Feynman shared the 1965 Nobel Prize in Physics for helping define how quantum physics work, but even he said: "If you think you understand quantum mechanics, you don't understand quantum mechanics." This didn't stop Feynman from proposing the idea of building a quantum computer though.

Incredibly, Feynman told a lecture hall at the California Institute of Technology that it was time to reinvent the computer in 1981. That's the same year IBM coined the phrase 'personal computer', or 'PC' for short. And it would still be another decade before these devices became everyday items.

But all computers – from those early IBMs to your modern-day MacBook – work by processing 'bits' of information. Each bit represents the value one or zero. This binary code forms the basis of all the calculations a computer can process. And the more bits a computer has, the harder the task it can handle.

A quantum computer, Feynman proposed, would use a quantum bit, or 'qubit'. These would exist in superposition, so they can hold both one and zero at the same time. If you were to quantum entangle two



Albert Einstein helped shape quantum physics theory, but disliked how it deviated from our classical understanding of the world

Source: Wiki

"This advanced processing power could help cure dementia or invent artificial intelligence"

Bits vs qubits

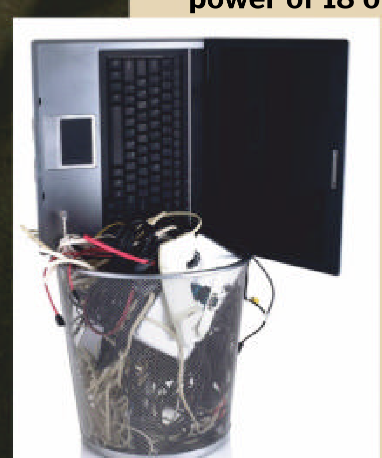
Traditional computers rely on silicon transistors that work like switches to encode bits of data, representing either one or zero. But no matter how many billions of transistors we pack into them, they can only be in one state – a particular combination of ones and zeros – across those billions of transistors. But a qubit, made from a particle, can be both one and zero at the same time thanks to superposition. So while ten bits gives you 1,024 combinations of ones and zeroes – which can represent one number between zero and 1,023 – a qubit can encode all 1,024 numbers simultaneously. Through quantum entangling, 20 qubits can encode over a million numbers at once. A hundred qubits would, in theory, be more powerful than all the supercomputers in the world combined.

Performing operations

A conventional computer operates in single bits, finding outcomes that are either one or zero. This means it can only perform calculations one at a time. A quantum computer, however, uses all its qubits – which are linked by quantum entanglement – simultaneously. This means it can work on a million calculations at once. This makes quantum computers exponentially faster and more powerful. However, the slightest interference – from a change in temperature, electromagnetism, a sound wave or physical vibration – can make qubits stop existing in multiple states at once. This can introduce errors into calculations or even slow quantum computers down to the speeds of a regular one.

Don't bin your laptop

The power and speed of quantum computing will make even the next generation of supercomputers obsolete. So-called 'exascale' computers will be able to perform a billion billion calculations per second. That's an impressive 10 to the power of 18 operations, but quantum computers will carry out 10 to the power of 1,000. Supercomputers are extremely specialist tools. When quantum computers replace them they won't be carrying out even ten per cent of the world's computing tasks. The average user needs a lot less computing power day-to-day and enjoys the portability that quantum computing may never be able to provide. If this changes, users could still connect to a quantum computer using a conventional computer via the cloud.



© Getty

The need to keep qubits cold means quantum computers like the IBM Q System One look like sci-fi fridges

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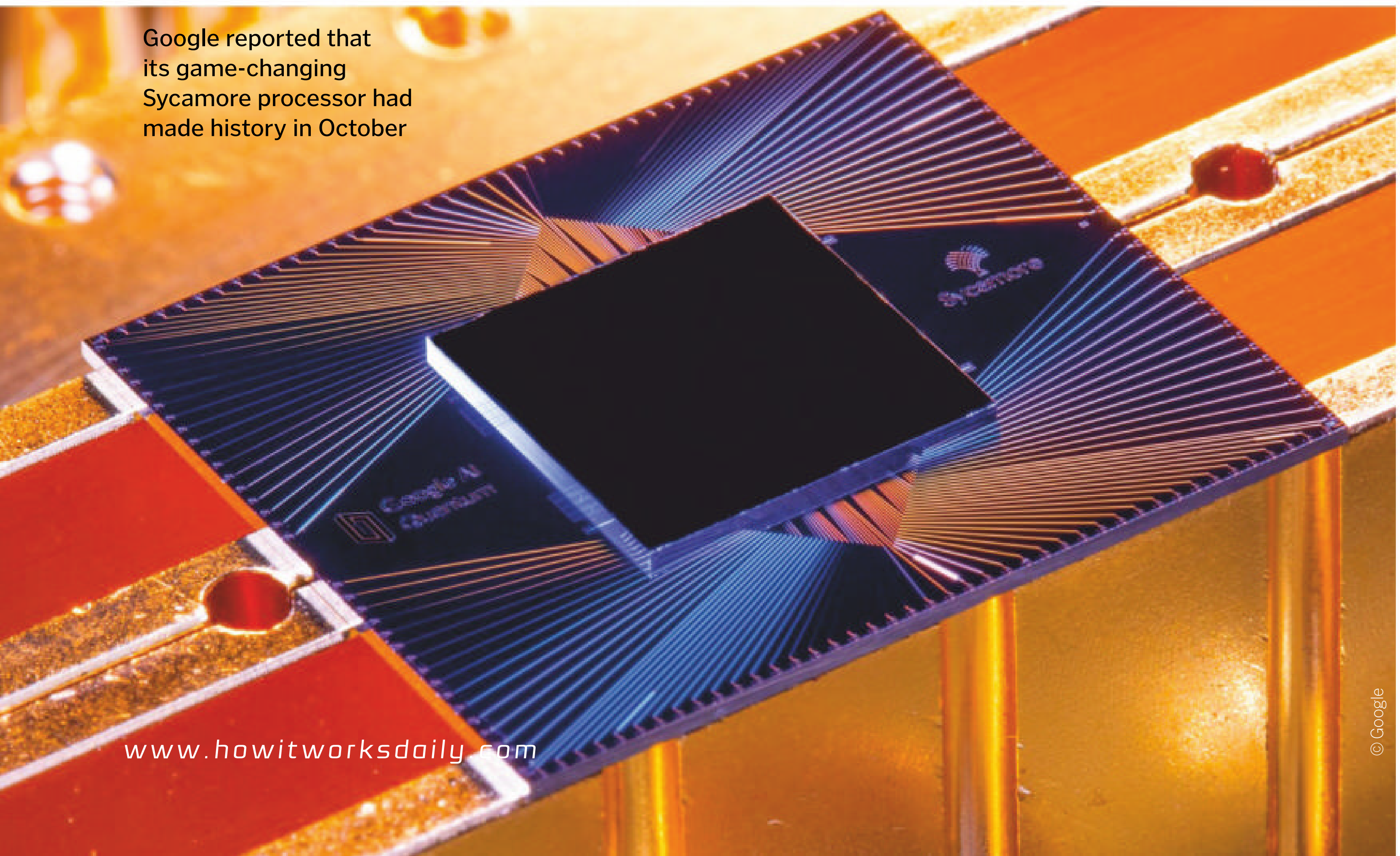

Google reported that its game-changing Sycamore processor had made history in October

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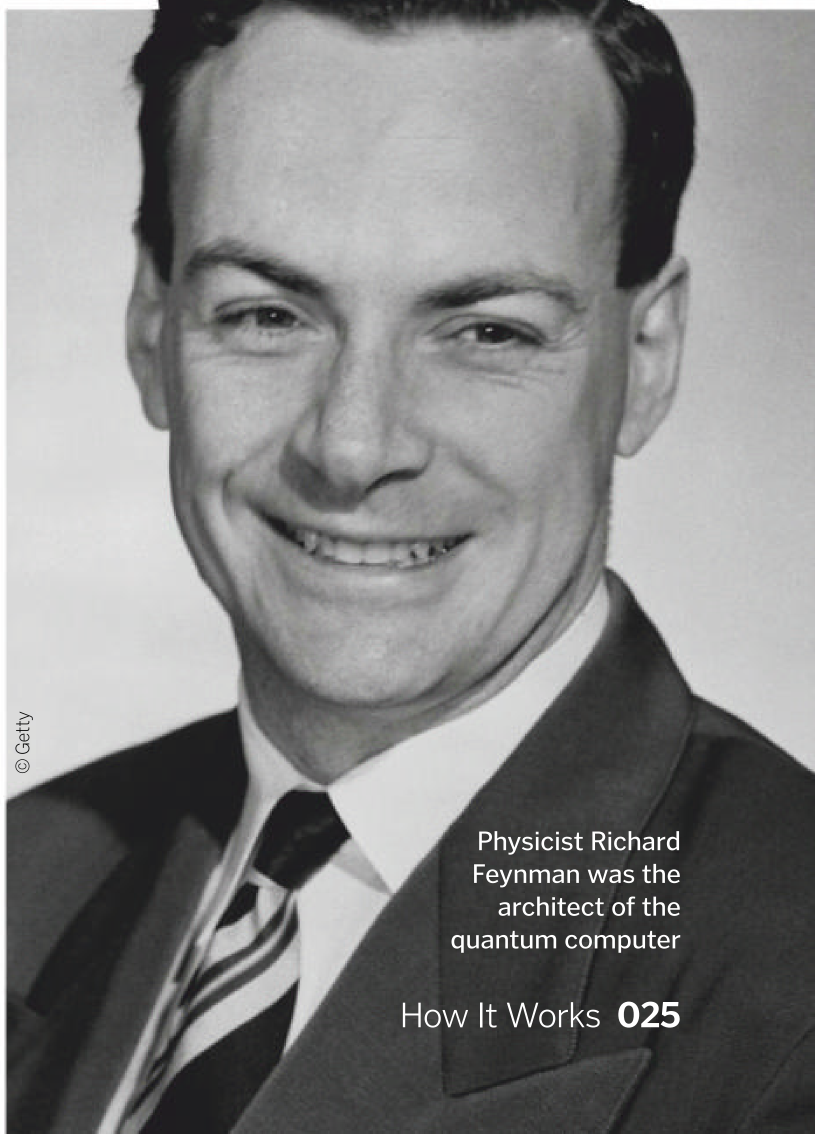
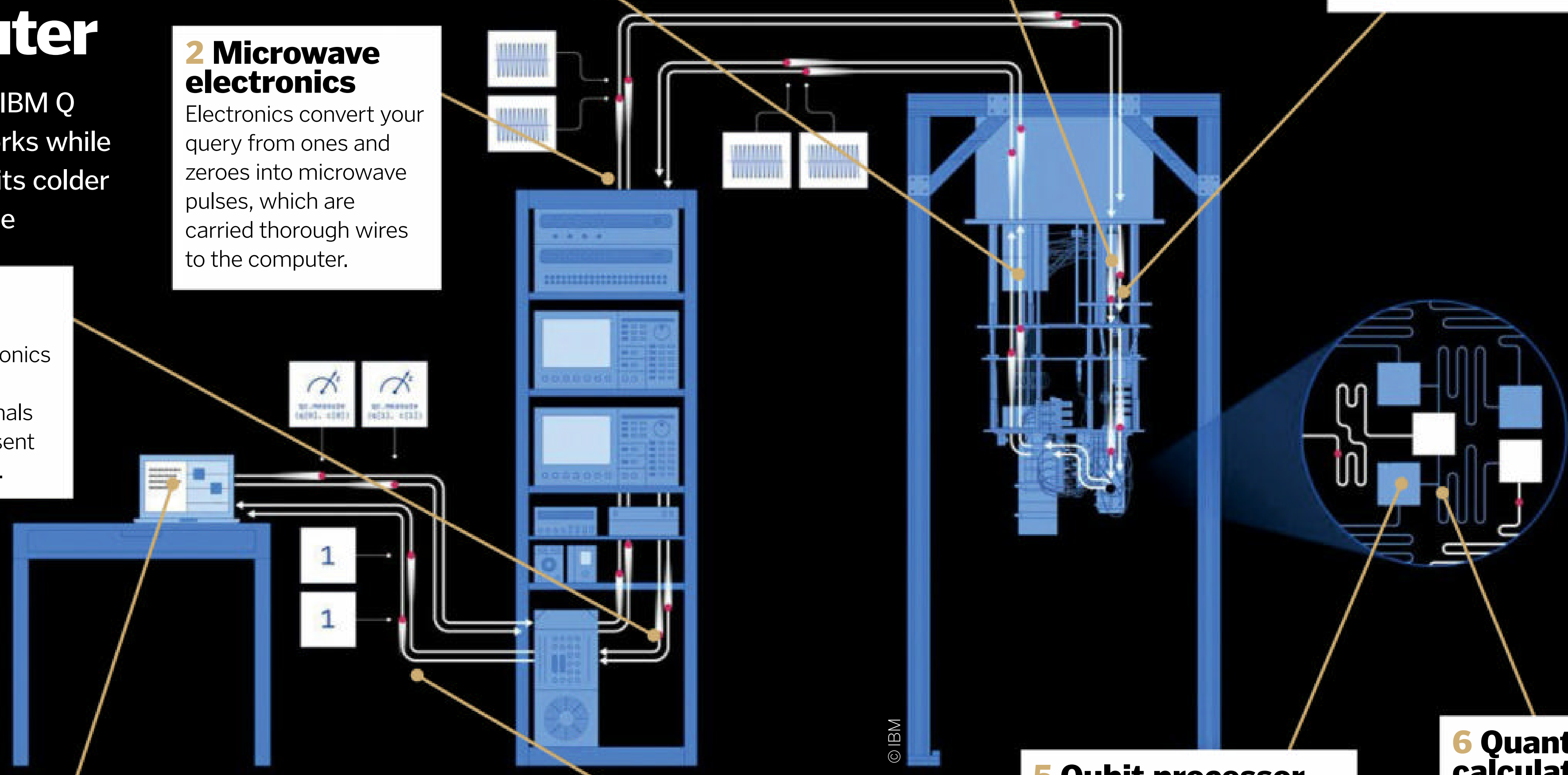


Physicist Richard Feynman was the architect of the quantum computer

© Getty

Inside a quantum computer

Here's how the IBM Q System One works while keeping its qubits colder than outer space



1 Ask a question
Using a conventional laptop as an interface, enter the problem you want to solve. Keep it simple, as today's system can't run many operations and stay cool.

2 Microwave electronics
Electronics convert your query from ones and zeroes into microwave pulses, which are carried thorough wires to the computer.

3 Input microwave lines
As the microwave pulses enter the system their signals are reduced, so their heat doesn't affect the qubits.

4 Multistage refrigerator
Two helium isotopes are mixed together in such a way that they create a reaction that absorbs heat, chilling the whole system down to -273.135°C.

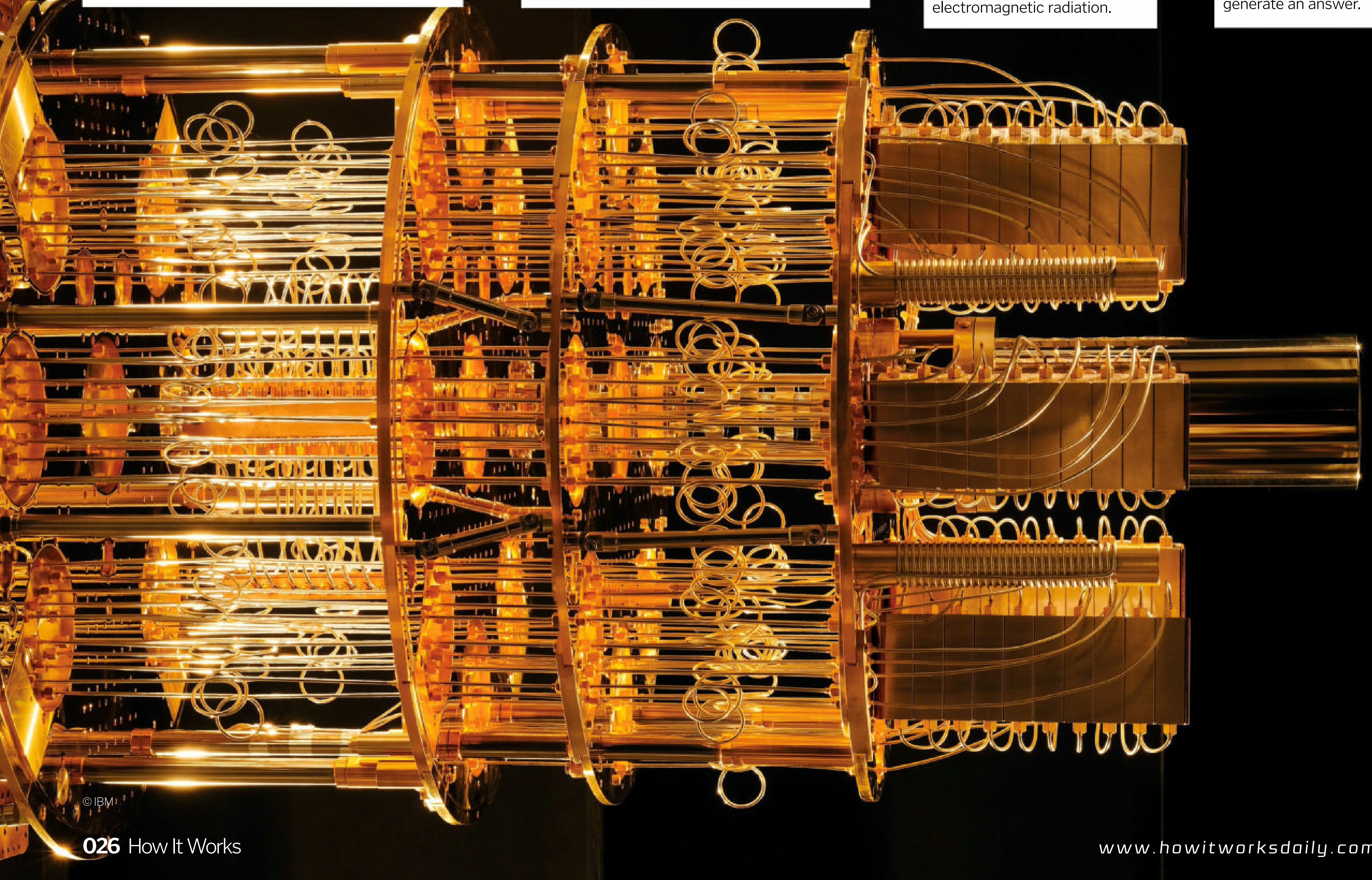
5 Qubit processor
The qubit chips – also known as 'transmons' – are stored just below the helium mixing chamber. Extra shielding also protects them from electromagnetic radiation.

6 Quantum calculation
The microwave pulses manipulate the qubits, adding or subtracting them from one another to generate an answer.

7 Amplifying the answer
Readout measurements from the qubits are routed through circulators. Amplifiers boost their signal.

8 Digital conversion
The bank of electronics digitises these measurement signals and an answer is sent back to the laptop.

9 Double check
This whole process takes a matter of seconds, but may need to be done several times as quantum computers have such a high error rate.



© IBM

qubits, they could hold four values at once: 1-0, 0-1, 1-1 and 0-0. As the number of qubits grow, a quantum computer very quickly becomes more powerful than a conventional one, so it can process information in a fraction of the time.

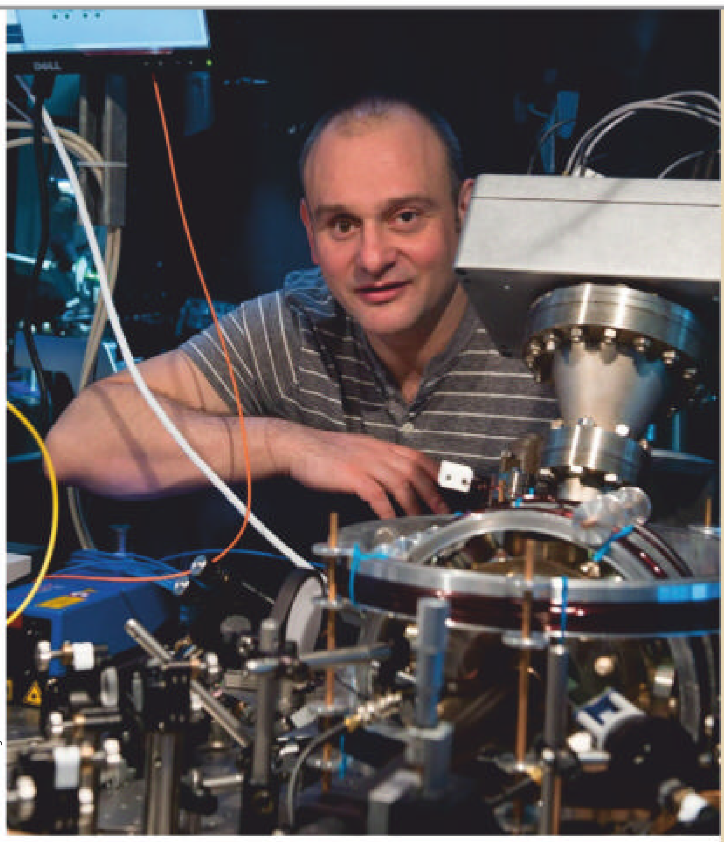
While Feynman provided a blueprint for how the technology could work, actually building a quantum computer proved much harder. Qubits are made from individual atoms or subatomic particles. Just trying to control them risks making them lose their quantum properties. Just linking them together took years of work, with the first two-qubit computer appearing in 1998.

This all changed over 20 years ago, when superconducting circuits were pioneered in Japan. This involves cooling qubits to -273 degrees Celsius using powerful fridges. Using this method, Intel has achieved 49 qubits, and IBM boasts 53. Google's game-changing Sycamore processor also has 53 qubits, but the tech giant's already built another with 72. A start-up with $119.5 million (£93 million) in funding called Rigetti even says it's working on a 128-qubit system.

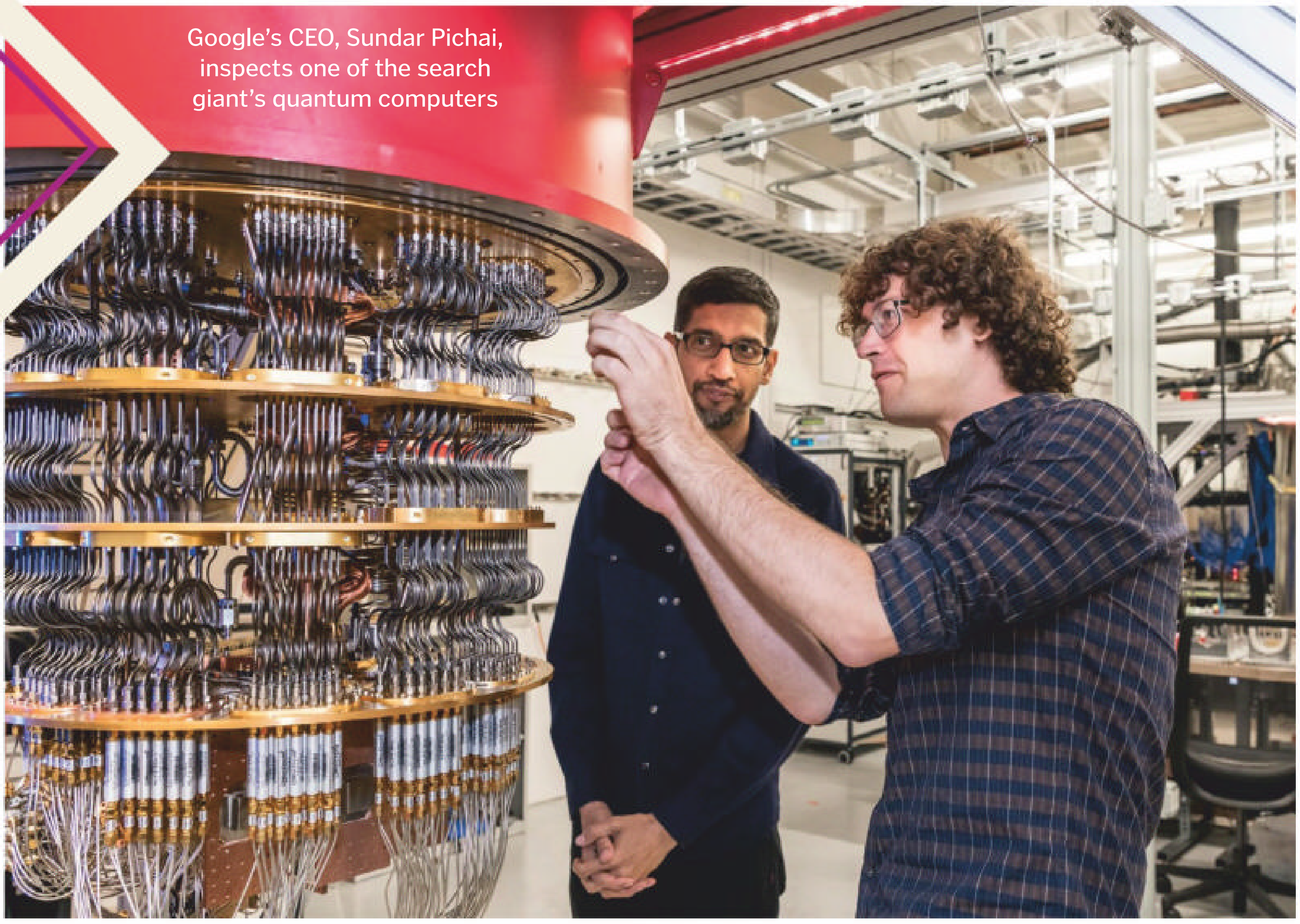
But it's harder to cool large objects than it is smaller ones, especially when you need them to be colder than the depths of space. So just as superconducting qubits have reached the size that they can achieve quantum supremacy, they may be about to outgrow the refrigerators they rely on.

One alternative is to use ions, any atom with an added electrical charge. These can be trapped using microchips that emit electric fields. Each microchip can then be used as a qubit. Crucially, these can work at room temperature, so solve the fridge problem. But trapped ions have only been tested in labs, and will take a long time to build on the industrial scale that's needed. Microsoft, meanwhile, is experimenting with topological qubits, which would be less sensitive to temperature, but this involves splitting electrons. You could say this technology is in a quantum state of its own: it's both making important breakthroughs and at the same time we're only just beginning to understand it.

"Feynman provided a blueprint for how the technology could work"



Professor Hensinger thinks trapped-ion quantum computers are the future



Google's CEO, Sundar Pichai, inspects one of the search giant's quantum computers

Q&A

"Quantum computers now are approaching those in the 1940s"

Prof Winfried Hensinger of the University of Sussex puts Google's achievement into perspective

How significant is Google's breakthrough?
It's a technical next step, but it's not necessarily as significant as some people think. What Google has done is solved an academic problem – one that is entirely useless in a practical sense. It's a problem that's chosen with one thing in mind: whether a quantum computer can do something a conventional computer can't.

So why are we talking about it?
Google's achievement demonstrates that quantum computers are not like nuclear fusion, which a lot of people often say is ten years away, but never actually arrives. When I started 20 years ago, people were very sceptical. Most of my colleagues rolled their eyes at me when I said I was going to build a quantum computer. That's because it's unbelievably hard to control the quantum effects of atoms. So what Google has achieved is still really nice, as it's demonstrated mastery of manipulating 53 qubits. That's a big milestone.

When do you think quantum computing will come into its own?
Quantum computing will likely follow the same development path as conventional computers. In the 1940s, conventional computers decided World War II by breaking the German Enigma code. However, while they were good for a particular task, they couldn't tell you train times, handle word processing or play video games. It was another 40 to 50 years until we used them for literally everything. It's a gradual process. Quantum computers now are probably approaching those in the 1940s. In the next five years, these machines will be able to solve one particular practical problem.

WHAT CAN QUANTUM COMPUTING REALLY DO?

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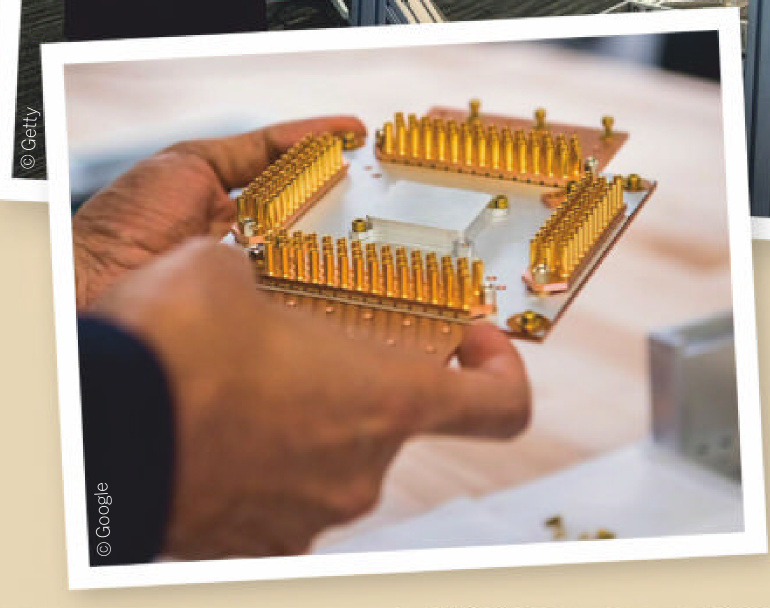

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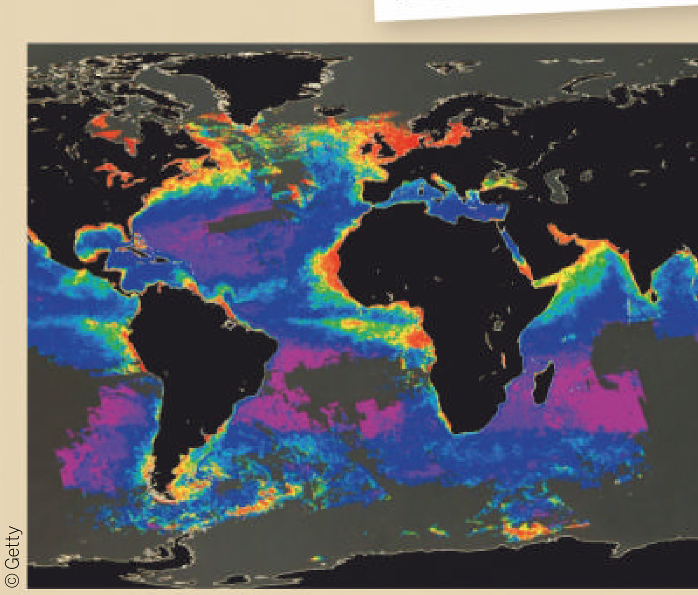
An exhibition model of IBM's Q System One quantum computer

A vital component of the computer: the quantum processor

© Getty

Create personalised medicines

Developing medicine is a long process. You can spend a lot of time and money just trying to find a molecule that can fight a disease. But with a quantum computer you could simulate complex drug designs in a matter of hours. This technology could even tailor treatments to a patient's DNA, making them more effective and reducing side effects. As each one would be unique, it'd also be much harder for viruses and bacteria to develop drug resistance.



© Getty

Combat climate change

Predicting the weather is hard because there are so many environmental variables, such as temperature, humidity and wind conditions. Beyond not having an umbrella on hand, faulty forecasts can cause travel chaos for airlines and affect farmers' crops. With a quantum computer, scientists could predict near-term weather patterns perfectly. And they could more accurately assess the long-term effects of climate change before they happen.

© Getty

End traffic jams

As the world's cities grow bigger and smart cars start to drive themselves, better navigation is going to be needed. As quantum computers can perform multiple calculations at once, they're very good at so-called 'optimisation problems', or finding the best way to do something. Volkswagen have used quantum computers to help taxis find the fastest route to an airport in Beijing and buses avoid traffic jams in Barcelona. The process could also help speed up deliveries.

© NASA

Find Earth 2.0

NASA believes a quantum computer combined with machine learning could process data collected by space telescopes much more efficiently, helping us find habitable planets. What's more, it could even help plan missions. By simulating the many challenges a robotic rover might face on a distant world – like when and where best to recharge their solar batteries – these probes could be better programmed to overcome them.

Source: Wiki/Benjah-bmm27

Design new materials

Back in 2016 – and working with just two qubits – Google engineers simulated a hydrogen molecule for the first time. Since then IBM has managed to model even more complex molecules. Just as this process might be used to design drugs, it could also make new chemicals and materials. This could include longer-lasting batteries, more efficient fertilisers for growing crops and even plastics that are biodegradable.

© Getty

Make the internet hack-proof

While current passwords take supercomputers centuries to crack, with a quantum computer you could do it in hours. You could access anything: emails, bank accounts, even state secrets. Fortunately, quantum mechanics might also be the solution. Quantum key distribution (QKD) sends information using photons. If you try to read these particles in flight, they'll lose their uncertain state – destroying the data they're carrying and alerting the sender.

An artist's impression of Google's Sycamore processor

-273°C

Temperature that researchers work with to preserve the quantum behaviour of qubits

1,203km

Furthest recorded distance between a pair of quantum-entangled photons

100

Microseconds it takes for a qubit to lose its quantum properties

$10bn

The starting cost of developing and building a quantum computer

50

The expected number of qubits a 'quantum supreme' computer would need. Google has 53

1,048,576

Number of states that a 20-qubit quantum computer can process at once


3D clay models create a versatile way to design cars' exteriors. Designers can etch fine detail into the clay

THE FUTURE OF CAR DESIGN

Take a peek into Ford's design centre to see how VR is being used to put cars together

Words by **Ailsa Harvey**

The new Ford Puma curved chassis was design using VR

What relationship do you have with your car? When cars were first created, they served one purpose: to travel from A to B. While this is inevitably still their core purpose today, the huge variation in designs generated by global car companies provides flexibility in both style and function. There's also an aspect of personalisation in the car-choosing process.

In Ford Europe's design centre, car designers are working with new technology to ensure the most effective methods. Recently they've been focusing on how best to create cars that are centred around humans and their personal tastes. As their head of design says, it does not just want to install "tech for tech's sake," but to benefit the people at the heart of the cars.

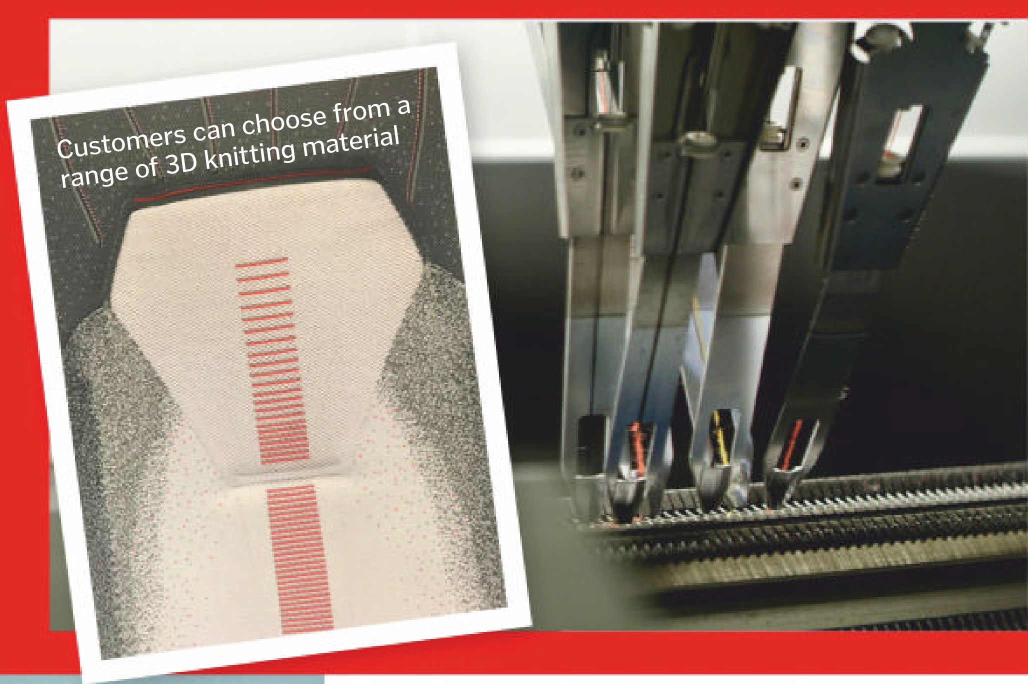
One of the main techniques to bring customer experience to the forefront of design has been a work in progress for three years. Interior designer Nicolas Fourny came up with the idea of turning his sketches into a 3D experience using existing VR technology. By virtually placing the design team into the car to experience their ideas before they become reality, they are able to create more practicality-focused vehicles. The added dimensions allow sections of the interior sketches to be slotted together and placed on a sphere: this creates a complete 360-degree view of their proposed interior before committing to dimensions in manufacturing.

As well as refining design methods, modern technology incorporated into cars' functions is helping Ford and other companies enhance the driver experience. Vehicles can detect your presence – the Ford Kuga model processes your movements around the car so that you can open the boot hands-free, for example. These subtle touches selected by designers aim to connect humans with car technology. Giving the illusion of cars and humans working together as a team, Ford hopes technological advancement can build stronger relationships between humans and their cars.

3D knitted seats

Ford is beginning to explore the possibilities of 3D knitting for its car seats. Using yarn material in a process similar to 3D printing, machines follow an algorithm with step-by-step instructions to knit the material into various shapes and designs. With this system the seat covers can be produced seamlessly, as large sections of material are knitted in one go.

This technology is new to the car design industry, but has been around for a while for applications such as running shoes and furniture manufacture. By creating larger, whole pieces of fabric, there are less production steps as a result. Cutting and sewing together fabric pieces is no longer necessary. In turn, this creates less waste material. Opening up doors to further design paths, the technology also allows the potential for built-in connectivity. Soon 3D-knitted car seats could be incorporating functions such as heating, door and window controls, wireless phone charging and driver health monitors.



Customers can choose from a range of 3D knitting material

Q&A

Amko Leenarts

We caught up with Ford Europe's head of design at its centre in Cologne to find out how technology is shaping design processes

What research is involved before designing a car?
We have two types of research that we do. One focuses on what a customer does on an everyday basis. We send designers out to live with the customer for a week to see how they live. Secondly, we explore the fears and the dreams of the customer. What do they love? Or what is it that they would ever want to do, or become? Our cognitive psychologist conducts a lot of this research for us. And then from this we create a design we think is appropriate.

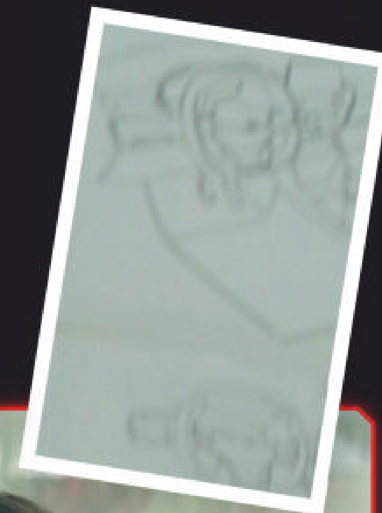
How is modern technology transforming cars?
It all comes down to how technology interacts with you, to enhance human experience. It's a series of emotions that I always like to refer to as a movie or a game.

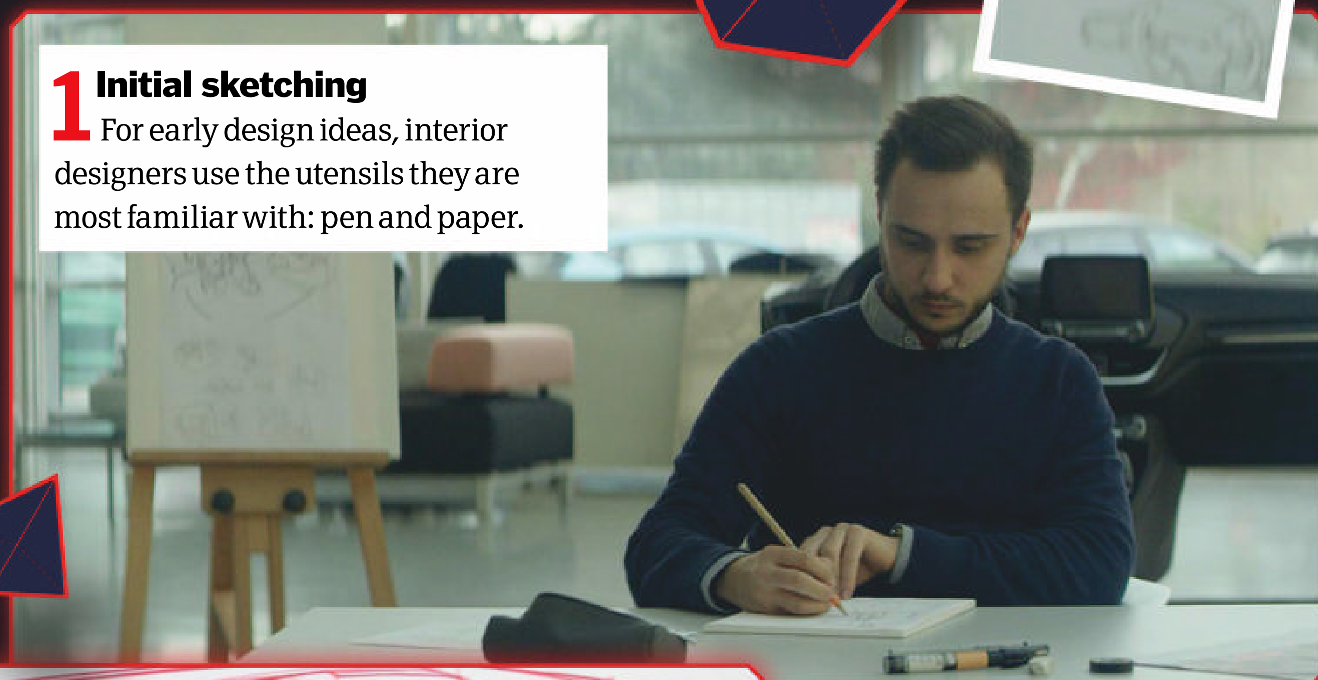
It brings this idea of a car as a friend, a butler or a working partner; that's what is making it so interesting. If you walk up to a car, some technology allows it to recognise you. It starts to communicate with you and then you feel like it's a relationship somehow.

In what ways is future car design evolving?
I think the biggest change is humanisation of technology – and that's not just 'Alexa' being nice. That's how objects are connected in a way that you trust them. Driverless cars will take a while because people don't trust robots yet. The moment that technology humanises the relationship between cars and humans, I think we win. Today people are looking to the future more than ever. That means the gap between customer expectation and what we're actually doing has never been bigger than right now. While technology is evolving quickly, the cars still take a couple of years to make. This discrepancy between customer expectation and what we can deliver puts us on a continuous edge.

HOW TO DESIGN CARS IN VR

What steps do car designers follow to transform a 2D sketch into a 3D model?

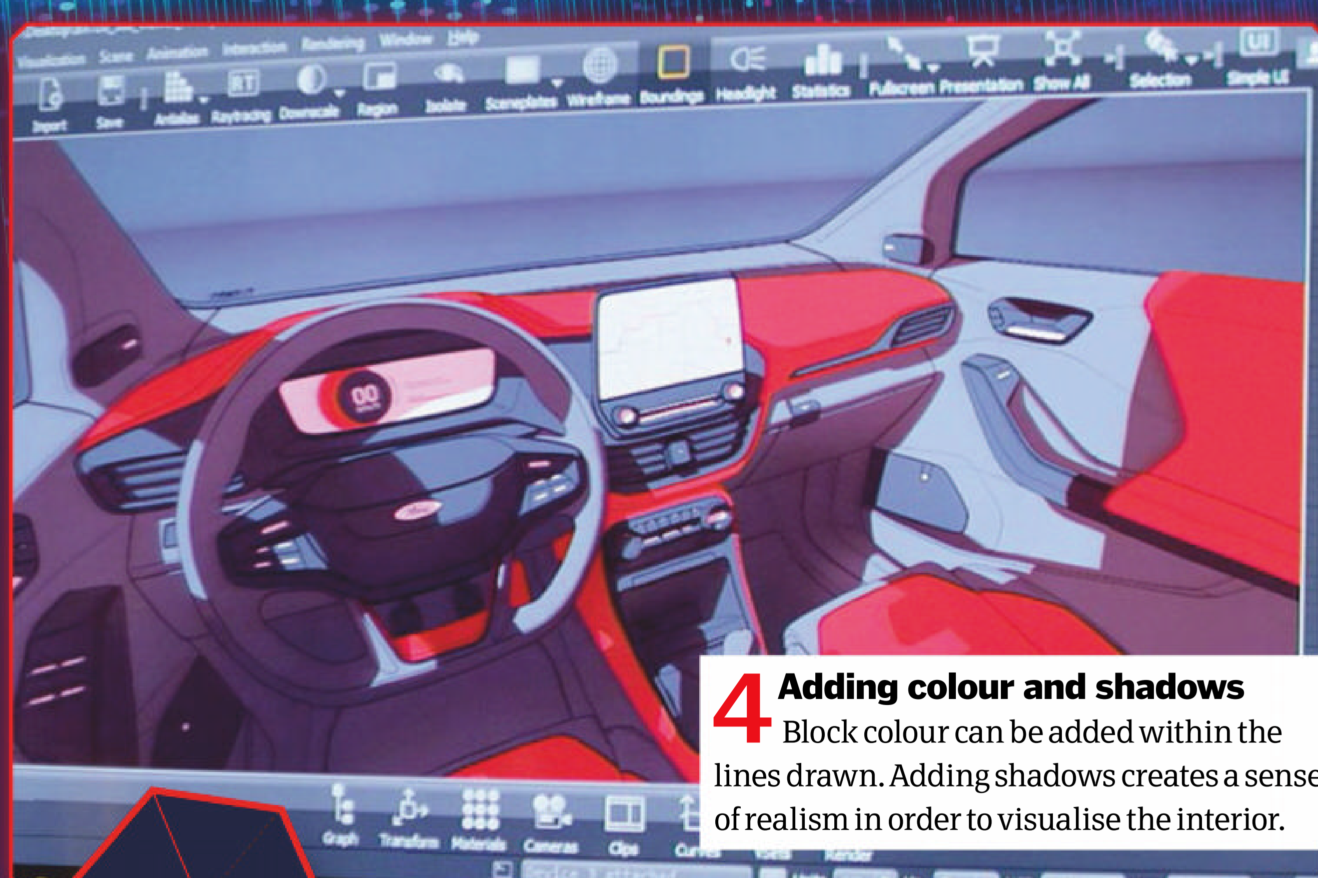




1 Initial sketching
For early design ideas, interior designers use the utensils they are most familiar with: pen and paper.

2 Sketching on the tablet
Moving to tablet enables layering, unlimited editing and the ability to experiment more.

3 Finer detail
Changing ink colour and pen thickness, the designer is able to use the initial design as a stencil while adding further features.



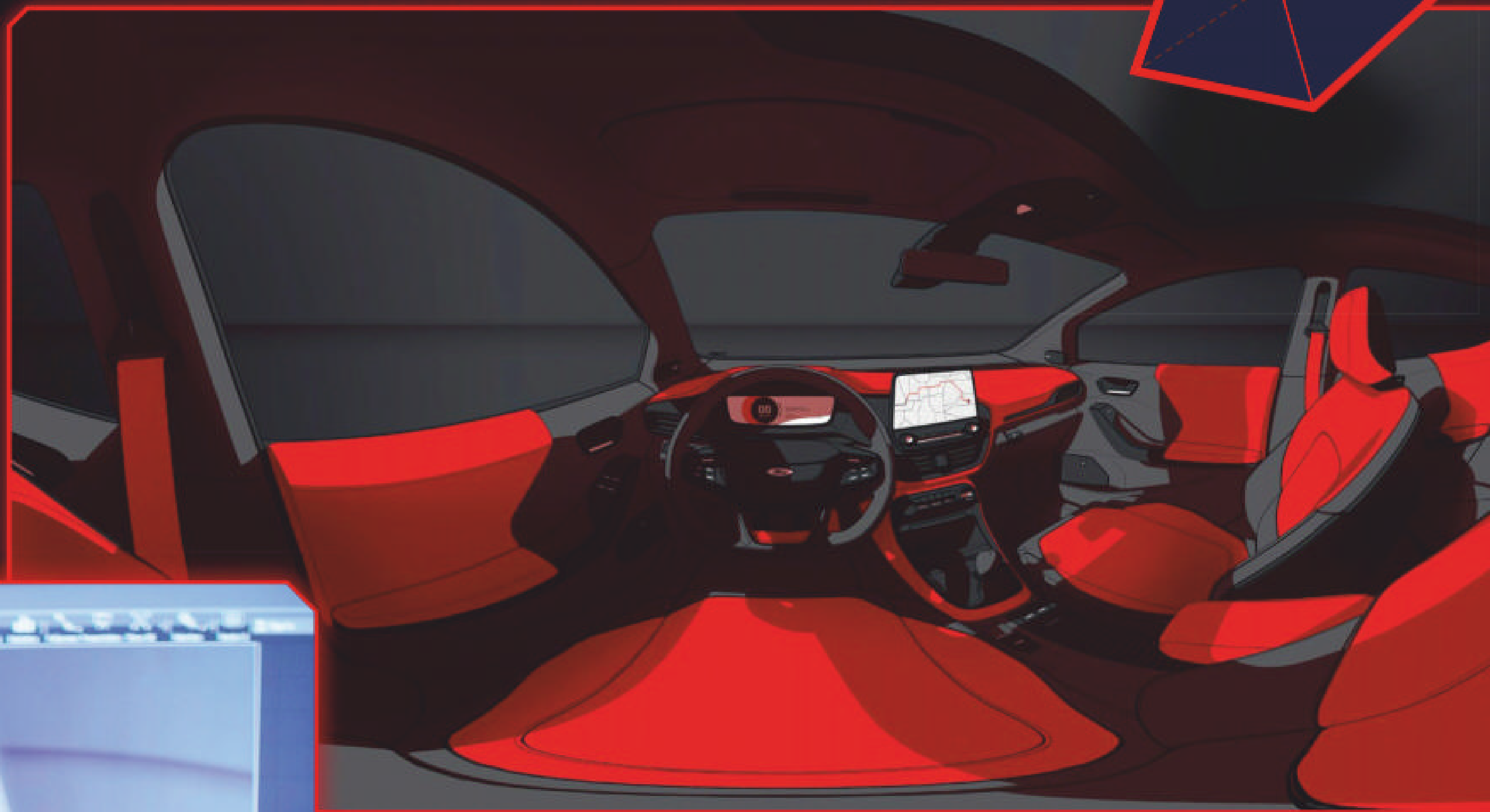
4 Adding colour and shadows
Block colour can be added within the lines drawn. Adding shadows creates a sense of realism in order to visualise the interior.

5 The stretched design

The first step towards 3D imagery is to recreate the design in a warped version to fit around a sphere. Like the globe of a map, the image will fit proportionally in the headset.

6 Headset transferral

Stepping into the VR headset, you're immersed into a 3D version of the design. This provides a view from the driver's seat to experience how it would feel inside the car.



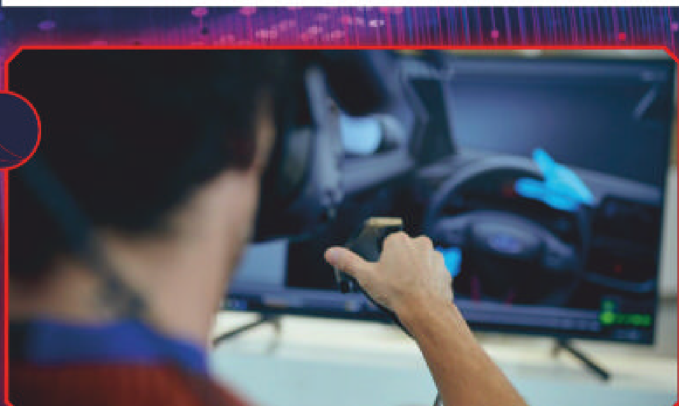
7 360-degree views

Inside the virtual car, you can turn around to see the rear of the car, and the design's placement around the driver. Here the designer looks behind him and up to the roof to analyse his work.

8 Sensing distance

Wands connected to the device can be held in your hands to demonstrate the proximity of the steering wheel, gear stick and other driver controls.

"These subtle touches selected by designers aim to connect humans with cars"



9 Experiencing the design

Designers can experiment with reaching for the wheel and gear stick to check their design's functionality.

10 Sharing the design

Selling the design to lead designers and communicating the concept with manufacturers are important steps. It can be demonstrated either by putting the VR headset on, or displayed on a large screen. This also enables zooming and rotating to focus on specific elements in detail, which couldn't be done previously with paper sketches.

WEAPONS FOR THE 21st CENTURY

FROM MICROWAVE GUNS TO CYBERWARFARE, A GLIMPSE INTO THE STRANGE NEW WORLD OF TODAY'S BATTLEFIELD

Words by **Andrew May**

Weapons have been around for thousands of years, and for most of that time their primary purpose has been to kill people, or at least to inflict serious injury. But in recent years the emphasis has changed. Alongside traditional bombs and guns, there's a whole new generation of weapons that aren't intended to kill. In many cases they aren't even designed to be used on humans, but against technology. The military's increasing reliance on computers and other tech has seen the rise of electronic warfare gadgets, as well as drones – some very sophisticated, like the X-47B pilotless stealth fighter pictured to the right – and anti-drone weapons.

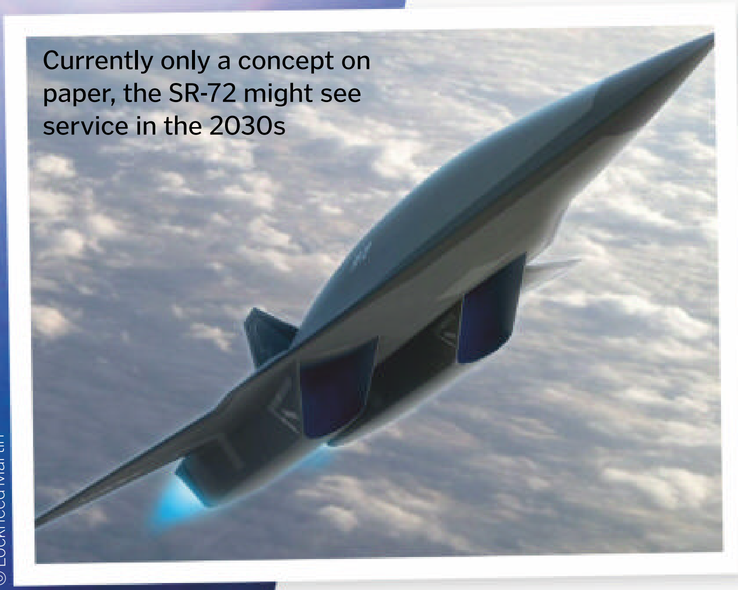
In the realm of 'non-lethal weapons', probably the best-known is the taser, which incapacitates its victim by inflicting an electric shock. Then there are laser dazzlers, which interfere with an enemy's vision without causing permanent blindness. Other options available to today's modern military include powerful acoustic waves and microwave beams, which produce extremely unpleasant symptoms without any physical injury.

Here we take a look at a selection of these new weapon types, alongside the more traditional 'futuristic weapons' – like space lasers and hypersonic jets – that science fiction has always been promising us.

© Lockheed Martin/Skunkworks

© US Navy

Northrop Grumman's X-47B pilotless combat vehicle



Currently only a concept on paper, the SR-72 might see service in the 2030s

© Lockheed Martin

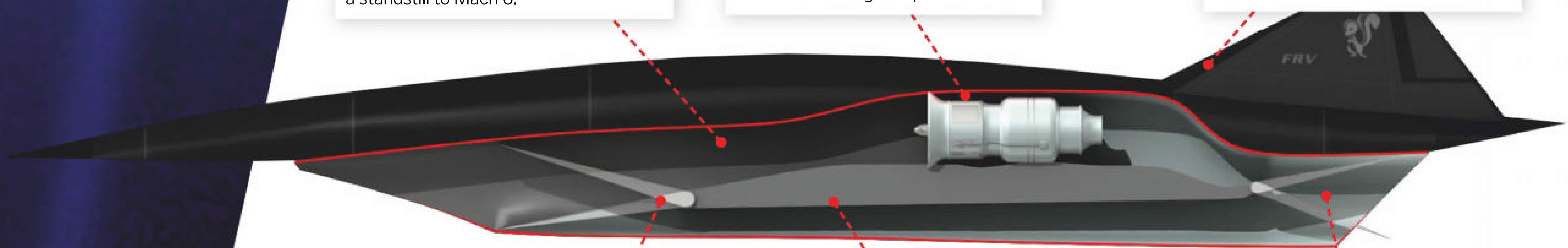
HYPERSONIC STRIKE PLANE

By the 1960s rockets could travel at hypersonic speeds – above Mach 5, or five times the speed of sound – but achieving such speeds with a jet-powered aircraft has proved elusive, posing huge challenges for aerodynamics, engine design and materials technology. These need to be overcome if the US is to meet its 'Prompt Global Strike' objective, to attack any target in the world within an hour. Lockheed Martin's SR-72 concept is an attempt to rise to this challenge.

Hybrid propulsion system
Two different engines are used, allowing the SR-72 to accelerate all the way from a standstill to Mach 6.

Turbojet
A conventional jet engine draws air into the combustion chamber with the aid of rotating compressor blades.

Heat-resistant materials
Above Mach 5, aerodynamic heating would melt an ordinary metallic airframe, so carbon composites and ceramics are used instead.

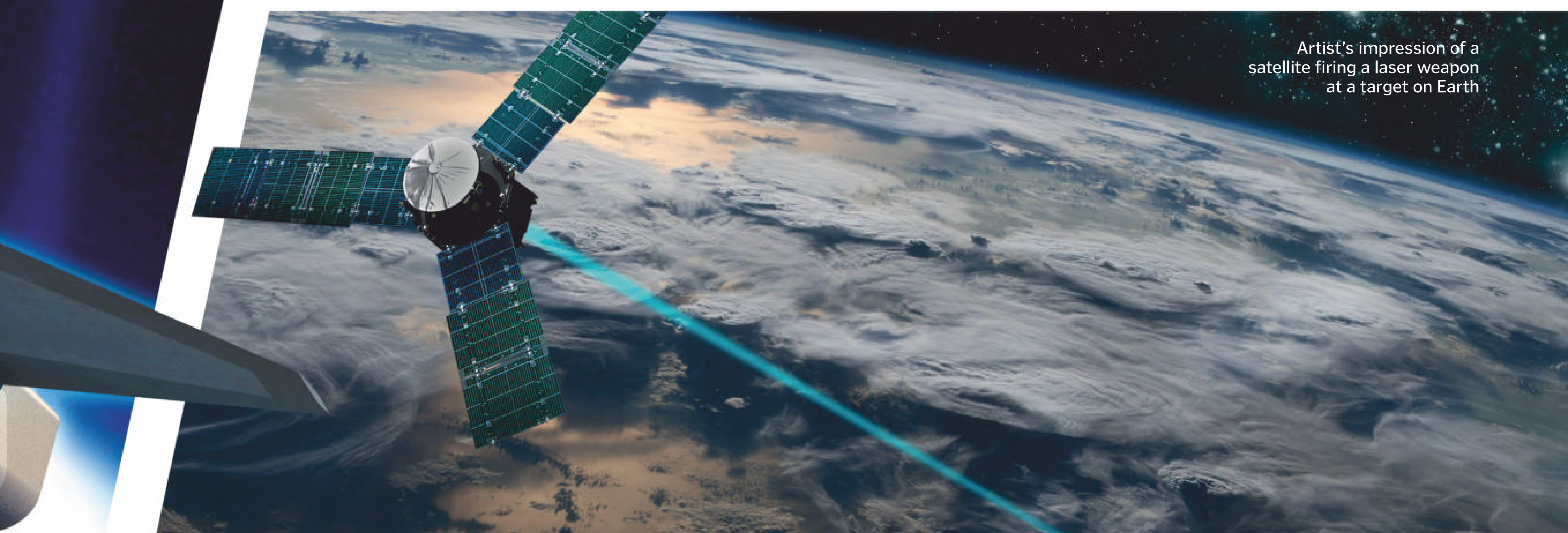


Airflow splitter
This directs incoming air to the turbojet at lower speeds, then flips to the ramjet above Mach 3.

Ramjet
Above Mach 3 the aircraft's speed is enough to compress the airflow without the need for moving parts.

Exhaust nozzle
Whichever engine is used, the result is a superheated stream of exhaust gas, pushing the aircraft forwards like a rocket.

AR ZONE! SCAN HERE



Artist's impression of a satellite firing a laser weapon at a target on Earth

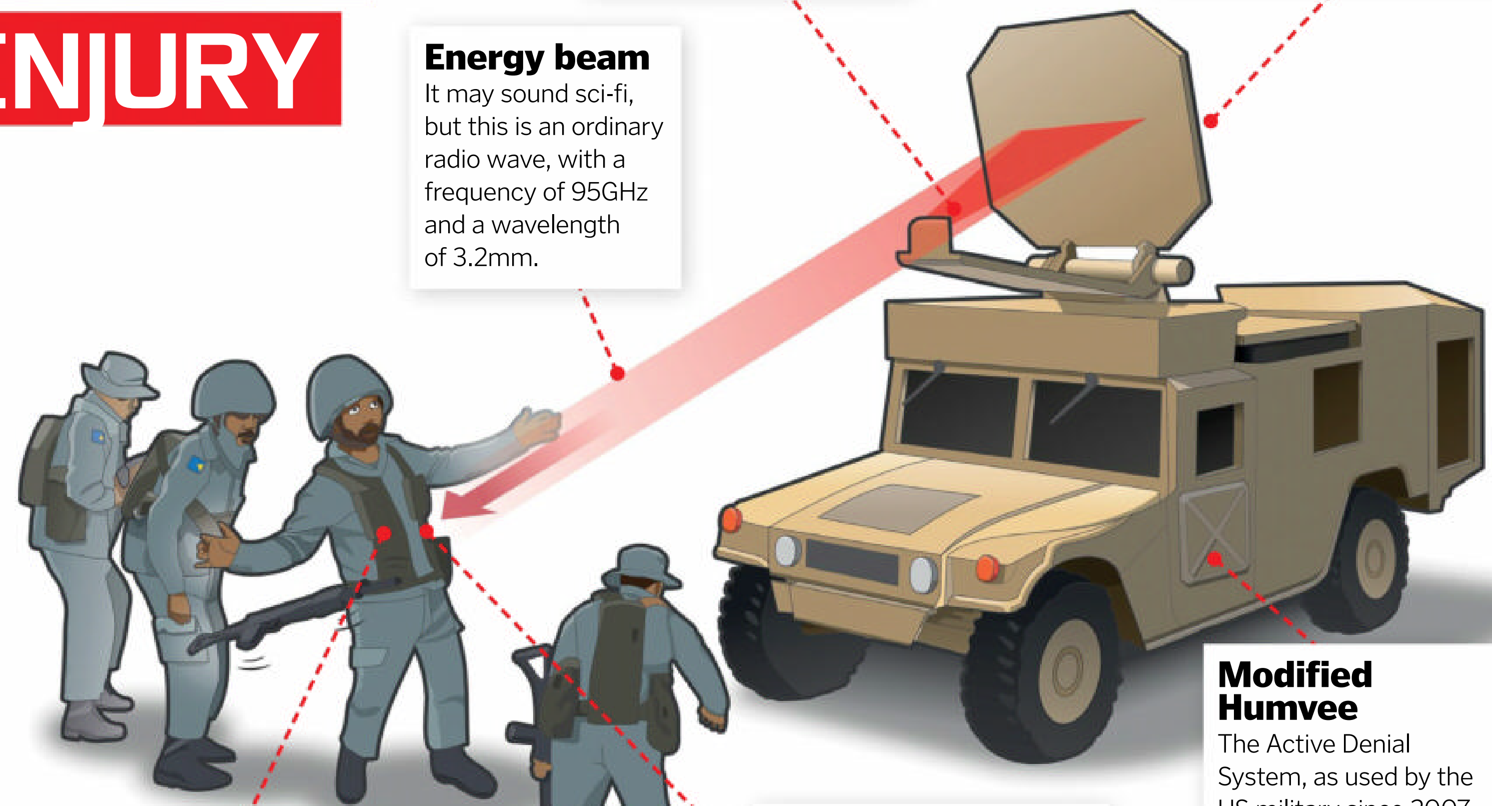
WEAPONS IN ORBIT?

A sci-fi favourite, the space-based weapon has never quite got off the ground in the real world. That's not for want of ideas though. People have often considered putting laser weapons into orbit, either to destroy other spacecraft or attack targets on Earth. Another futuristic-sounding option is the electromagnetic railgun, using electric fields rather than gunpowder to accelerate a projectile. A space-based version capable of vaporising a ballistic missile using shells fired at four kilometres per second was proposed way back in 1986. Even weirder is the concept of 'kinetic bombardment' – essentially an artificial meteor storm in which heavy tungsten rods, irreverently dubbed 'rods from God', would rain down from a satellite onto a designated target such as an airfield or heavily defended building.

© Getty

INFLICTING PAIN WITHOUT INJURY

If you want to stop an enemy as quickly as possible, killing them is one option – but not the only one. You can cause them to feel so much pain they immediately back off. That's the thinking behind the Raytheon company's Active Denial System, which makes anyone on the receiving end feel like they're being burned alive. They're not really being injured at all, but even if their conscious mind knows that, the pain is so great they pull back involuntarily.



© Illustration by The Art Agency / Nick Sellers

5 FACTS ABOUT
QUIRKS OF WEAPON DEVELOPMENT

1 Nukes are yesterday's weapons
Nuclear explosions create powerful electromagnetic pulses, instantly burning out every electronic circuit within several thousand kilometres. This means they're incompatible with the highly digitised world of modern warfare.

2 Space warfare is slow
Satellites travel very quickly, but only in predefined orbits. Gradually changing the orbit to fly right over the desired target may take several days.

3 Secrecy – good or bad?
New weapons are traditionally 'top secret' so other countries don't copy them, but knowing about a weapon can deter enemies from attacking – so too much secrecy is a bad thing.

4 Weapons versus weapons
The 1960s saw the emergence of anti-missile missiles – weapons aimed at defeating other weapons. The idea caught on, and modern weapons are often designed to counter a specific enemy weapon.

5 Not killing = not legal?
According to the internationally accepted rules of war, shooting to kill on the battlefield is legal – but non-lethal weapons that "cause superfluous injury or unnecessary suffering" are not.

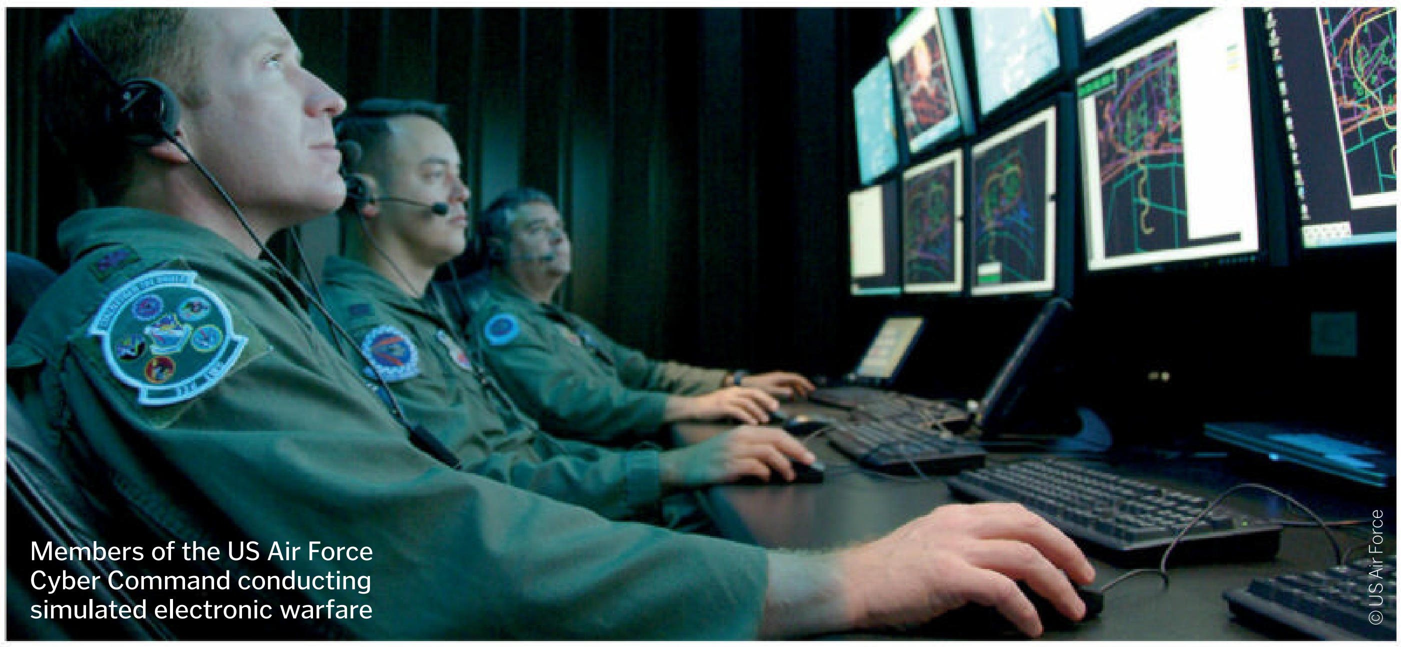

Soldiers of the Italian Army testing an anti-drone jammer on a rooftop in Rome
© Italian Army


© US Navy
A US Navy crewman using a laser dazzler against a simulated attacker

"Other options produce extremely unpleasant symptoms without any physical injury"

ELECTRONIC WARFARE

Technology plays such a key role in modern warfare – in data collection, communications, information processing and decision-making – that a whole range of devices have been developed that target an enemy's tech. Electronic attack aircraft, such as Boeing's EA-18G Growler, carry a suite of transmitters that can jam radio and radar systems, or even inject false signals into them. Computer networks can be compromised through 'cyberwarfare' – the United States Cyber Command has been one of the US military's 11 unified commands since 2018. But the ultimate anti-tech weapon has to be the electromagnetic pulse – colloquially known as an E-bomb – which is designed to wreak havoc on an enemy without physically destroying anything or injuring anyone. It works by producing a sudden blast of electromagnetic energy that burns out all the computers and other electronic systems within a wide area.



Members of the US Air Force Cyber Command conducting simulated electronic warfare

© US Air Force

LASER WEAPONS

The sci-fi weapon of choice, the 'energy beam' exists in the real world in the form of lasers. At the low-power end are non-lethal dazzlers – actually less dangerous than laser pointers, because they use a broad beam to avoid permanent eye damage. At higher power, lasers are proving to be the perfect anti-drone weapon. In a military context, drones pose a unique threat because they're small and nimble, and can attack in swarms. Laser beams have an advantage over bullets in travelling at the speed of light – and they don't need reloading. The US Navy tested a prototype using a 33-kilowatt laser in 2014, and has now ordered a 150 kW version to be fitted to several of its ships. Even that pales in comparison to the US Air Force's megawatt-class Airborne Laser Testbed – a modified Boeing 747, scrapped in 2011 because it was too cumbersome for operational use.

© US Air Force

The Airborne Laser Testbed, designed to destroy missiles in flight, proved too impractical for use

How wireless charging works

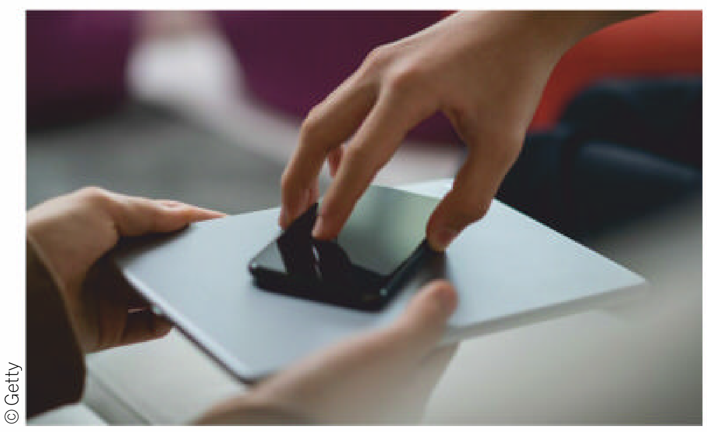
A breakthrough that took place over 100 years ago has led to the convenient new charging technology of today

When we think about electricity, many of us automatically envisage wires, whether it's fumbling around behind the television to connect the correct cables, seeing electricians work a colourful wire maze in an electric box – or simply taking out your phone charger when your battery level becomes critical.

These days the number of wires we need for our electrical devices is reducing all the time, and wireless power can now bring life back to electronic devices without the need for a physical connection. Wireless power technology uses charged particles to pass energy between devices before it's converted back to electrical energy.

It was Nikola Tesla who showed the world that wires weren't essential in power transmission in 1890. Using two copper wires, a primary coil could withstand massive amounts of charge. Once at maximum charge, the voltage was sent into the gap between coils, reaching the secondary coil, which was then able to produce lightning bolts. His 'Tesla coil' was first to demonstrate this concept, and while the breakthrough stood alone as an amazing invention, it would be over a century before the technology was used commercially.

Now wireless charging demonstrates a range of purposes and possibilities, that varies depending on how far the energy needs to be transported. Near-field applications use magnetic fields, while further distances, such as for in-space applications, require more complex techniques involving microwaves. This is often referred to as power beaming.



© Getty

Wireless charging technology allows charge to be shared between devices

Beaming power through the roads

Electric cars are coming thick and fast, transforming the way we use and view vehicles. New power sources mean reviewing the best method of charging – and wireless could be the answer.

Instead of plugging in your car to charge, all that is required is to drive over a panel on the floor. This panel acts as the transmitter, while the car's battery acts as the receiver.

In comparison to the phone charger, cars demonstrate this process on a bigger scale. This means that the technology currently in use needs development to ensure the system is not only easier for drivers, but faster as well.

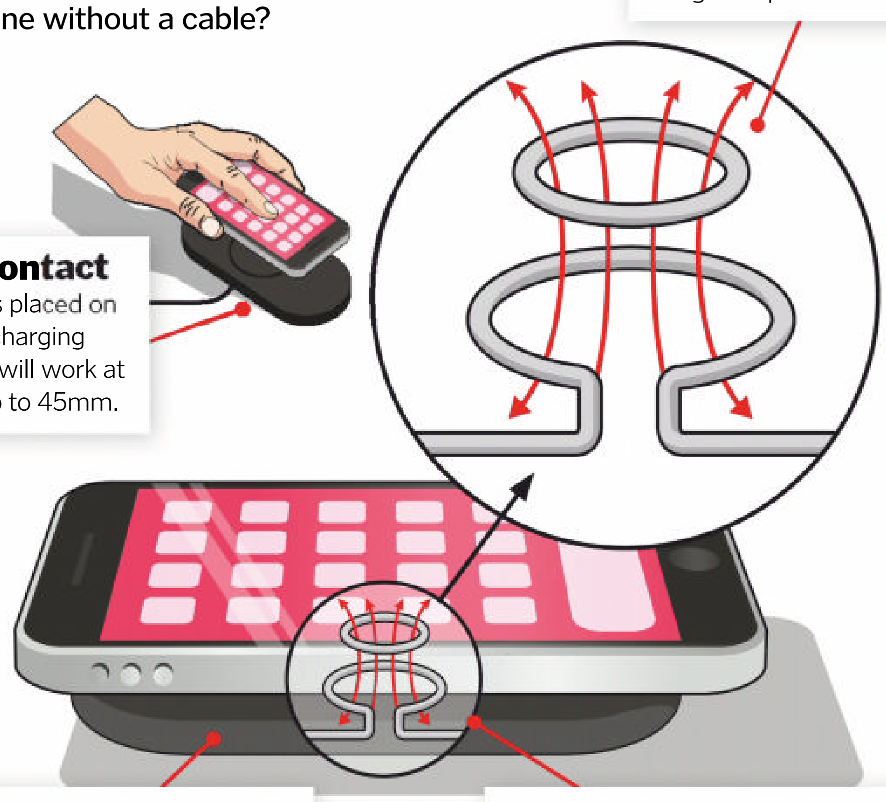
In the electric-driving future, the days of finding the nearest garage could be gone. Motorways may eventually be fitted with these power panels, charging your car while you drive over them.

Source: Wiki/NJo

A wireless car charging demonstration in Tokyo, Japan

Phone charging made easy

How can you charge your mobile phone without a cable?



Coil communication
The magnetic field created between the phone and the plate induces a voltage used to charge the phone.

Phone contact
The phone is placed on or near the charging device. This will work at distances up to 45mm.

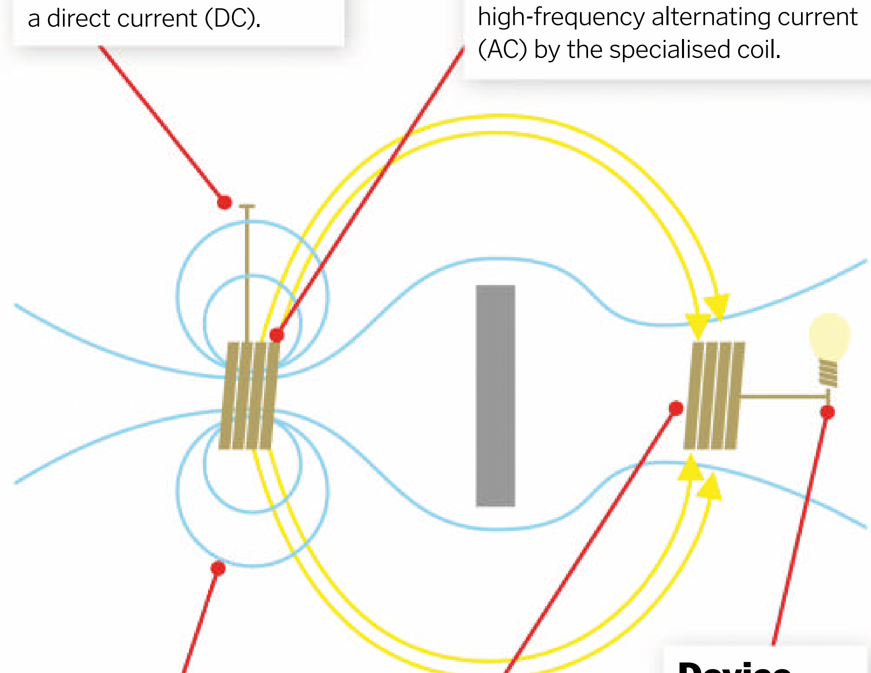
Magnetic charging plate
The charging plate is AC-powered. When the phone is placed on top they are connected magnetically.

Key components
The plate's transmitter coil and the coil in the phone need to be close. The phone needs to be fitted with this coil for wireless charging to work.

© Illustration by Ed Crooks

The wireless process

How energy is transported through the air



Plugging in
The power source supplies a direct current (DC).

Transmitter coil
The current is converted into a high-frequency alternating current (AC) by the specialised coil.

Magnetic field
Inductive energy moves across the gap through a magnetic field created by the AC current.

Receiving coil
The receiving device uses the electromagnetic energy to convert back to DC or AC.

Device
The power, back to the form of an electric current, is used to light the bulb.

ANIMAL ARMOUR

Discover how these thick-skinned species protect themselves in the wild

Words by **Scott Dutfield**

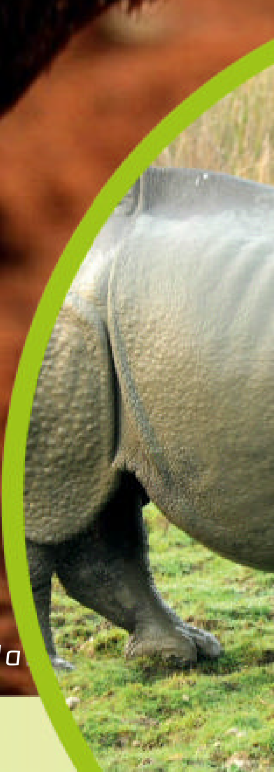
Trying to survive in the wild can be a tough game. Animals don't always know when danger may leap out at them from the forest or from the air, so having a natural suit of armour can come in handy.

One collection of animals are well-known for their armoured appearance. Arthropods, six-legged invertebrates including insects, crabs and scorpions, strut around in a hardened suit called an exoskeleton for protection. Made from a tough chitin-protein material – or calcium carbonate if you're a crustacean – this all-encompassing armour does not expand as the animal within it grows, so a new suit needs to be fashioned every time its armour becomes too tight a fit. Replaced in a process known as moulting, when an animal such as a crab has outgrown its exoskeleton it will absorb some calcium carbonate from the old shell to form a new soft one beneath. After releasing an enzyme to detach its old suit, the freshly dressed crab will break away and wait for its new shell to harden, hoping that predators don't spot it in the meantime.

Having a fortified natural suit isn't exclusive to the arthropod world, extending to reptiles such as crocodiles, tortoises, fish species such as the alligator gar and also many mammals.

One of the most iconic armoured mammals is the armadillo. Covering the majority of this small creature are around 2,000 tiny scales, also called scutes, that have erupted from their skin to form a shell-like exterior. Known as the carapace, a term also attributed to the shells of turtles, this tough exterior is made up of the robust protein keratin. However, this suit of armour is not designed as a rigid barrier for physical protection, but has evolved in such a way that the armadillo can curl up to form a protective ball. Growing in three distinct sections, the scapular shield at the front and pelvic shield at the rear sandwich rows of sliding armour in the middle. This telescopic design, similar to that of woodlice, gives the armadillo its ability to curl up. Not all armadillo species can form a complete spherical shield. Seven-banded armadillo, for example, lack the space beneath their shell to tuck all their limbs and head within. The three-banded armadillo, on the other hand, has a scaly suit that transforms it into a biological ball thanks to some extra shell room and shielding on its head and tail.

Armadillos aren't alone in their preference to curl up into a protective ball; pangolins also form a scaly sphere for safety. Found across Asia and parts of Africa, pangolins defend themselves from large carnivores, such as lions and tigers, with a coat of armour that covers almost their entire body. Made from the same material as an armadillo's, these keratin scales not only act as a hard defense, but are also designed to redirect any fractures from reaching the soft body below. Due to the humid environment these animals favour, the keratin armour remains hydrated and tough, whereas in a drier climate their scales would be more brittle and susceptible to cracks. Although pangolins might be shielded from other animals, humans pose the biggest threat to their survival. Believed to be the most trafficked animal in the world, more than a million have been taken from the wild and sold for their scales and meat since 2000.



The thick, segmented skin of the Indian rhinoceros appears as several pieces of rigid armour, but is flexible enough to allow movement

© Getty

An ancient armoured fish

Swimming through Earth's prehistoric waters, these armoured giants once dominated the waves. Spanning around nine-metres long, Dunkleosteus was one of the biggest fish during the late Devonian period, between 382 and 358 million years ago. What made this giant fish different from its modern-day descendants was its exterior head armour it wore. This helmet-like armour was made from bone and also covered Dunkleosteus's thorax and jaw, which could chomp through the bones of its prey with ease. As a keen carnivore, when prey species became scarce it's believed these sea giants turned to cannibalism to survive. Despite its physical protection and bite power, like the other 75 per cent of species on Earth, Dunkleosteus died out during the Devonian mass extinction around 375 million years ago.

The name Dunkleosteus comes from the Greek for 'Dunkle's bone'

© Alamy

How does a three-banded armadillo roll up?

1 The three-banded armadillo is equipped with three protective sections in its carapace: the front, middle and rear.

2 When threatened the armadillo begins to retract its limbs and arch its back to form a ball.

3 The triangular shape of the armadillo's head and tail scales fit flush with the surrounding shield to form the final armoured ball.

Dressing in a coat of armour doesn't just protect an animal against the physical attacks of predators, but also helps prevent invasions from parasites. By covering the soft, blood-filled parts of their body, animals such as pangolins and armadillos limit their exposure to blood-sucking parasites and pests. In turn, their risk of picking up a parasite-transmitted disease or infection from a bite is reduced.

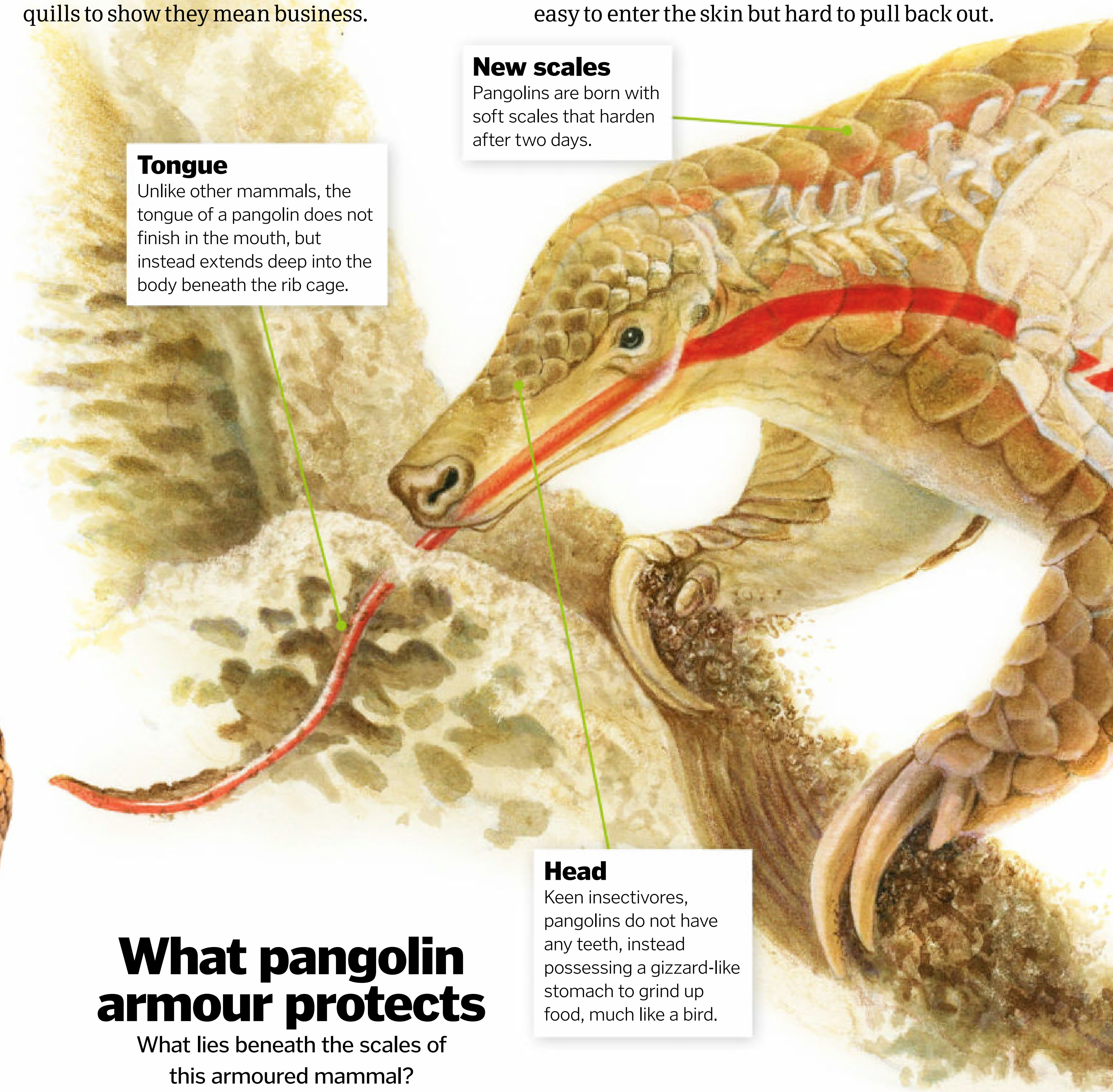
Being shielded by a protective layer of thick skin, a hard shell or a series of scales can help prevent the advances of a predator. However, some species use their body armour to go on the offensive. Mammals such as the hedgehog and the egg-laying echidna are armed with thousands of spines to ward away any unwanted visitors. But the king of prickly protection is the porcupine, native to Africa. Armed with sharp quills spanning between 2.5 to 30.5 centimetres long, porcupines are not easy prey. They're typically seen dashing through woodlands and rocky outcrops, and while moving their quills are flattened to form a spiky tail. When facing off with a predator, porcupines will raise their quills to show they mean business.

Pangolins curl up in a foetal position, making it almost impossible for predators to break through

These quills essentially grow in the same way our hair grows, in a cycle that results in tough, hollow spines. Quills are often found buried in the chins of animals that have had an encounter with a porcupine, leading to the common misconception that porcupines can fire their quill at will to impale predators. This is not the case: porcupines merely release quills from their bodies once they have punctured the skin of another animal. At the tip of each quill, rows of hooked barbs coat the surface, making them easy to enter the skin but hard to pull back out.

What pangolin armour protects

What lies beneath the scales of this armoured mammal?

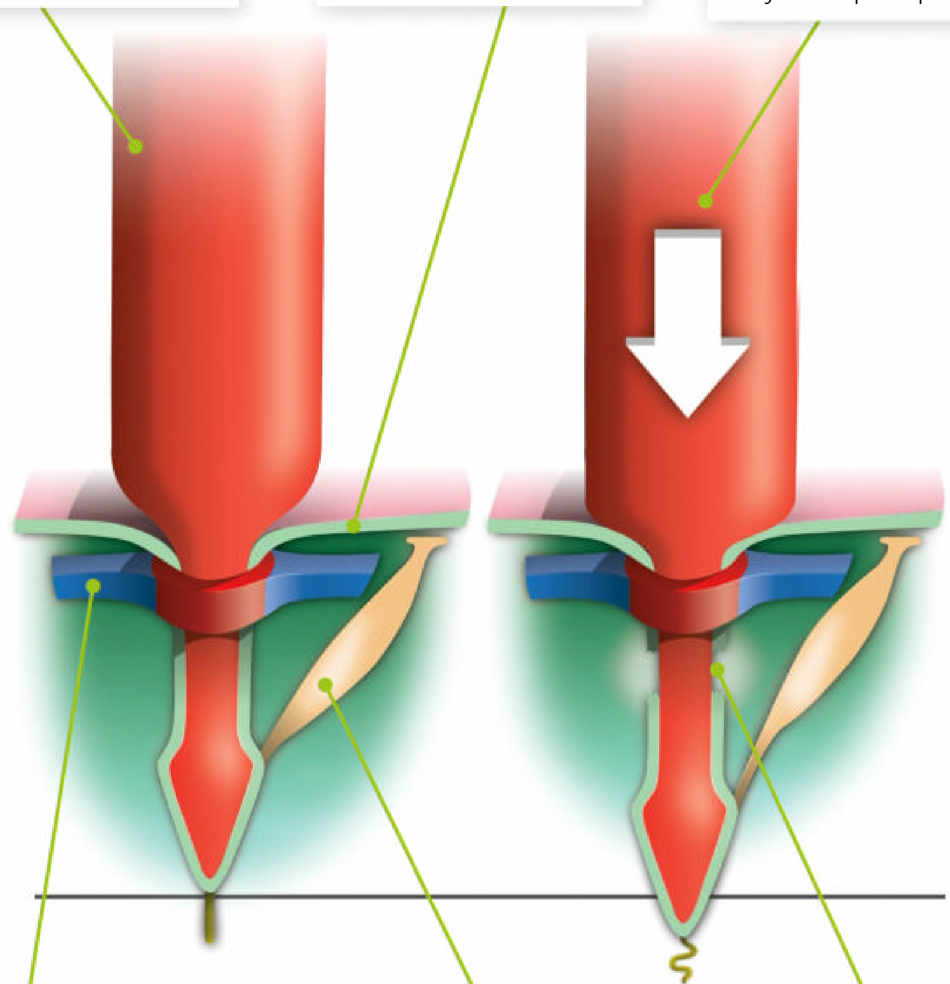


When confronted by a predator, porcupines will raise their needle quills for protection

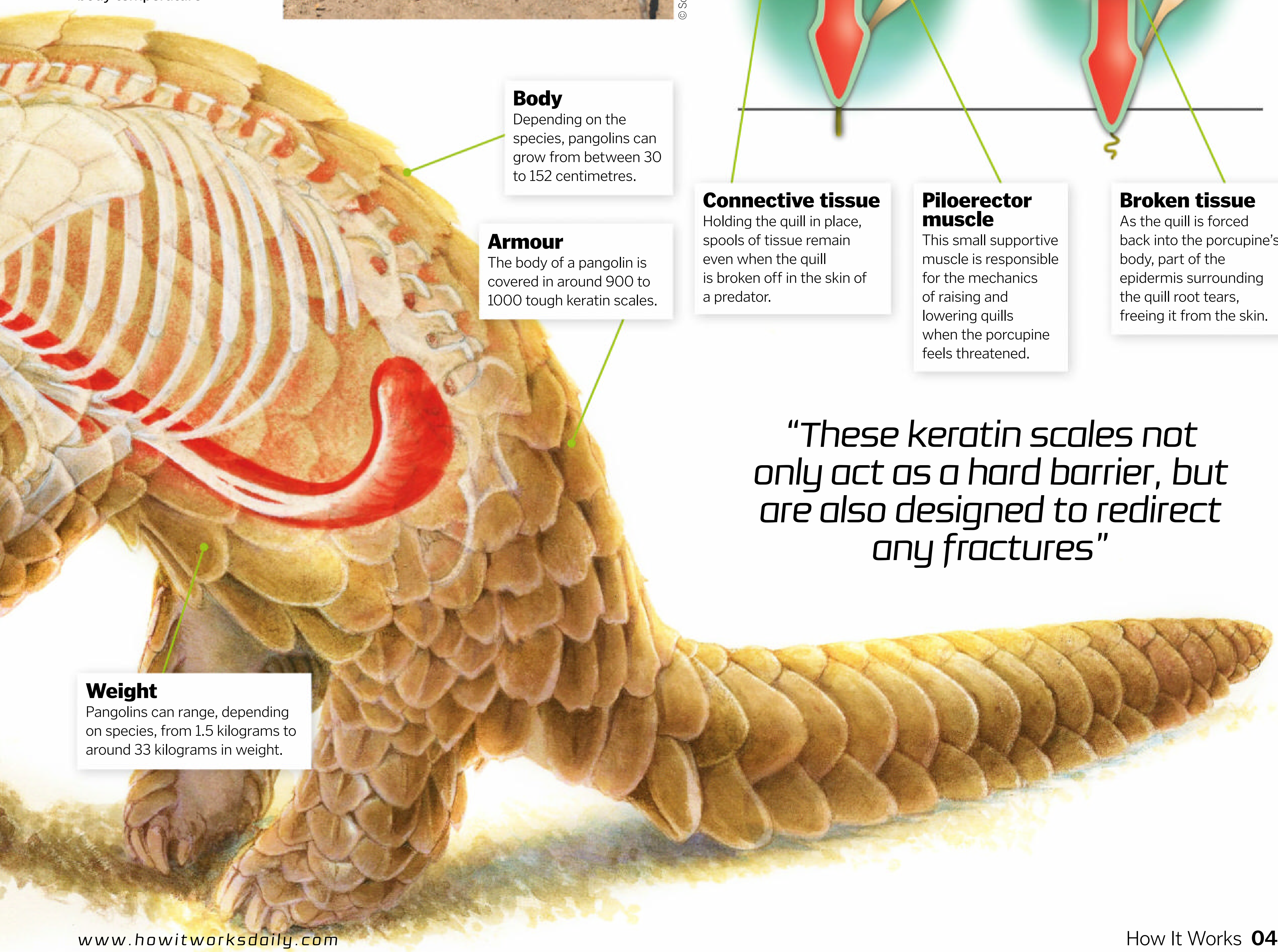
The pink fairy armadillo is believed to use its armour to regulate its body temperature

Releasing quills

How porcupines turn predators into pincushions



"These keratin scales not only act as a hard barrier, but are also designed to redirect any fractures"

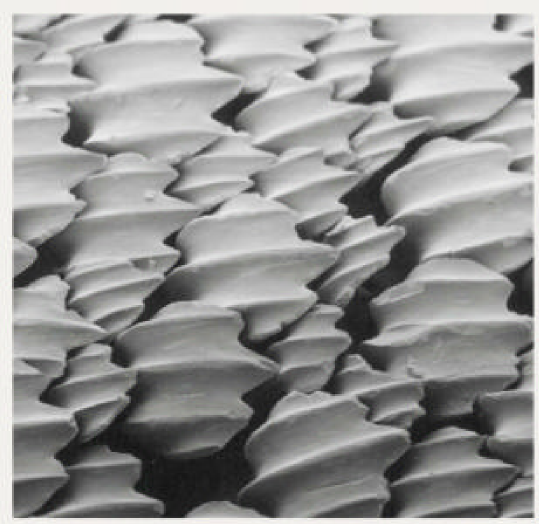


THE SECRETS OF SKIN

Professor Ben Garrod is a TV presenter and professor of evolutionary biology and science engagement at the University of East Anglia. He explores the evolution of skin and scales in a new BBC documentary series

Some vertebrates have transformed their skins from shields into weapons

Garrod visits the National Museum of Ireland to explore species' form and function



A lemon shark's skin viewed through a scanning electron microscope

Source: Wiki/ Pascal Deynat/Odontobase

What inspired you to undertake this series in particular exploring the secrets of skin?
I like the style of this series, because it's not purely a stand back and look at the grandeur of nature, it gets deep down and dirty with the science and explores how different things operate. We wanted to look at skin in particular because you often see documentaries on big sexy topics, like bones and blood vessels and hearts, but skin seems to get overlooked and taken for granted. When you look at skin quite analytically and then through the magnifying glass, it really transforms and becomes not just this barrier between us and the outside world, but this whole story in itself. I thought that story needed to be told from a scientific perspective and in a fun, engaging way.

How versatile is skin? How has it evolved as a result of changing environments?
In terms of versatility, skin can accommodate everything from polar temperatures to surviving in plus-40 degrees Celsius and then everything in between. We have animals that can shed their skins, shed their tails, change colour in a second and then back again. We know that cuttlefish can change colour and the texture of their skin from one that's beautifully smooth to one that's full of [hair-like] filaments instantly. Skin enables animals to fit into every environment imaginable. And that's why it's one of those sexy topics. It's not just this passive barrier; it's an interacting organ between us and the outside world. It's exploiting and interacting with the environment itself and others living in it. In terms of versatility: imagine a situation or an environment or a habitat and there is a skin to accommodate that.

The environment plays a massive part in how a species evolves and adapts, but what are other driving forces in skin evolution?
This is probably why skin is so diverse in terms of its form and function, because it's subject to all different things, like predator-prey relationships. That's easy to see when we can look at species like armadillos and tortoises. On the predator side, sharks, for example, have these dermal denticles, these tiny backward-facing teeth. Basically the shark is covered in millions upon millions of teeth all over its body, and they are able to swim in these very fast dynamic behaviours because they've got this very streamlined hydrodynamic covering over their body. That allows fast-swimming sharks, like makos, to carve through the water.

We've seen predator-prey as a selective evolutionary pressure for skin – also anti-parasite. Poison dart frogs, for example: we think part of the reason for them being so toxic isn't solely for anti-predation, but [the poison] also works as anti-fungal and antibacterial chemicals. So they're basically a little self-cleaning hand wash thing, jumping around the

Discover more about the science and evolution of skin with Professor Ben Garrod's BBC4 documentary series, *The Secrets of Skin*

Garrod looks at the amazing variety of skin found in the natural world at Bristol Museum

Lizards can shed their tails to avoid predators

forest. They're evolving to out-compete one another both in terms of predator-prey and in terms of parasites and pathogens.

Then there's sexual selection, everything from the peacock, with its massive bright tail, to mandrill monkeys. The wonderful, brightly coloured faces of these beautiful monkeys – which are sometimes 800, 900 strong within their communities – [are used to avoid] physically fighting and causing lots of damage – as they've canine teeth larger than a lion has. The risk of fighting with those teeth is obviously very high, and can cause death. But by having these brightly coloured faces, the change in intensity and coloration as they sexually mature stops fighting, injury and death [as mandrill society respects the hierarchy]. So there's a whole range of different things driving evolution.

Are there any species that have skin that is poorly adapted to their environment?

If a species lives for any period of time in its environment, by default it is well adapted, otherwise it will be out-competed. Even animals that seem really rubbish: for example, a naked mole rat, which put above the ground would be dead in minutes. But underground, where it lives, their skin is amazing. They're like little animals that live in sleeping bags, walking around underground with this soft but tough skin. We know that they live much longer than any other rodent of their size, we know they don't get cancer, we know they don't get bacterial infections in the same way that other animals do. That skin is perfectly adapted for its environment. We see it again and again across many species. In the right context, what seems like a good adaptation will very often be a way of promoting his genes. The biggest area that I can play with and almost tempt you into believing there is a poor adaptation is in sexual selection. The best example of this is the peacock. This animal is so big and so heavy with its feathers… it's a massive 'here I am' to every predator in the area. It's absolutely counterintuitive and it has confused biologists and naturalists since at least the 18th century.

But evolution is just natural selection, and a big component of that is sex selection, which very often plays against natural selection. Individual animals don't need to survive, it just needs its lineage to. There are some animals that have bad skin, feathers, hair and scales, which of their own accord might increase his or her (usually his) chance of being killed, but will hopefully promote the chance of passing on their genes to the next generation.

How have you condensed such a large subject of evolution into a six-part series?

In terms of picking the actual stories, it's like a buffet. I can't have everything off the buffet. You just take a couple things from here and there and you get a nice selection, and that's what we did with this series. We've picked some of the weirdest and most wonderful aspects and examples of skin-based evolution behaviour and adaptations, but also we've allowed a narrative across here. We've broken down to the six main topics.

The very first one introduces adaptations as a welcome to skin – just some of the big broken-down areas that I would look at as a biologist. These are topics I would teach my students, and I think the series breaks it down to sizable chunks that are cohesive and have a narrative among them. For example, looking at simplistic communication, such as bird feather colouration. It's a way of saying either 'bugger off', or 'let's invest and have chicks'. That's quite simple communication, but then the series looks deeper, such as colouration under a UV lamp to see what their skin is showing. Each episode in itself tells a story, but then each episode builds this bigger picture, and by the end of the series you'll have gone from understanding how skin is a barrier, to what does it do? What makes up skin and feathers, hair and scales? I think it's an introduction to anyone who hasn't really ever thought about skin in a big way. Also, the nice thing is this is for kids and families, but also academics can watch this as well.

"Your skin itself is as alive with different species as the Serengeti or the Amazon"

What will viewers find most surprising from the series?

It's that your skin is not as passive an environment as you think. Your skin itself is as alive with different species as the Serengeti or the Amazon or even the Great Barrier Reef. There's as much living on you as there is in any of these places around the world, and ultimately you are never alone. In this series I go and meet some of my nearest neighbours, literally, and it's not nice. We look at skin on a microscopic level and there are things living on and in my skin that I really didn't anticipate. It really made me appreciate that if skin wasn't all on the outside it would all be inside, and that's not a good thing to have. I hasten to add that it wasn't just me that got tested, it was my team as well.

Why do glaciers retreat?

Find out how some of Earth's most impressive frozen features are disappearing

Glaciers form in areas of snowfall where conditions are cold enough to allow snow to lie until it has frozen into ice. Ranging in size based on climate conditions and snowfall levels, many are the remnants of the last ice age, when frozen peaks covered over 30 per cent of all land.

Referring to them as remnants gives the impression that these frozen spectacles are declining. Currently these thick ice blocks dominate 15 million square kilometres of our planet, but as human activity continues to increase global temperatures, glaciers are reverting back to water at a faster rate than they would naturally.

Melting Alaska's mightiest

Glaciers form high in snowy mountains, so it is no surprise that Alaska is an area bountiful in these colossal ice blocks. In fact, Alaska is home to the world's thickest glacier, the Taku Glacier. Towering a mighty 1,480 metres from its surface to the ground, scientists studying the block have stood in awe of its ability to appear unsettled by global warming.

That was until recently. Glacial developments have always been used as a visual representation of our impact on Earth's climate, but the world's thickest was not only surviving, but thriving. The icy giant continued to expand, as it had been doing for nearly 50 years, seemingly unphased by the shrinking of its glacial neighbours. But now, by comparing aerial photos taken by NASA in August 2014 and then in August 2019, the glacier's size is visibly reduced.

In most natural glacier cases studied, they stop advancing for at least a few years before beginning their retreat, so this case has come as a surprise to many glaciologists.

© NASA Earth Observatory

An aerial shot of Taku Glacier, imaged by the Landsat 8 satellite

It's not unusual for glaciers to be subjected to melting during their lifetime, but they run on a continuous snow budget. If they lose ice quicker than they receive their income of fresh snow, their mass begins to diminish and glaciers begin to retreat.

Glaciologists analyse the activity of glaciers year on year. Studying individual glaciers can provide insight into which are growing, which are sustaining their mass and which are retreating. This being said, specific locations come with their own patterns, and a glacier's state depends heavily on its surroundings.

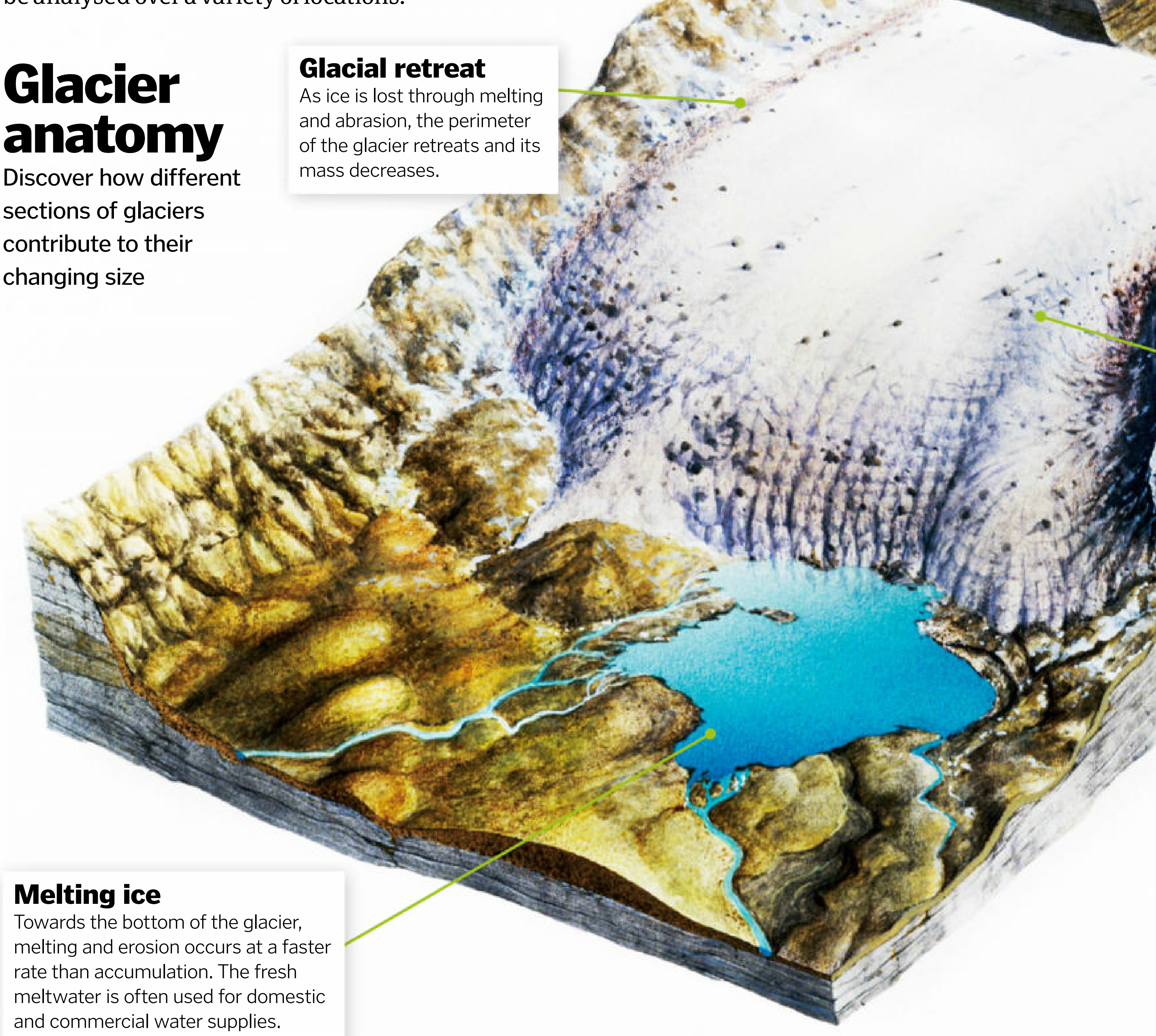
To an extent, glacial retreat is natural, and the causes of this can vary from temperature and evaporation to wind scouring. The build of these structures can often be season dependent, meaning a slight summer decrease is nothing to worry about, as the winter snowfall will make up for any mass lost as the season continues. Determining global glacier patterns for unnatural retreating requires long-term data to be analysed over a variety of locations.

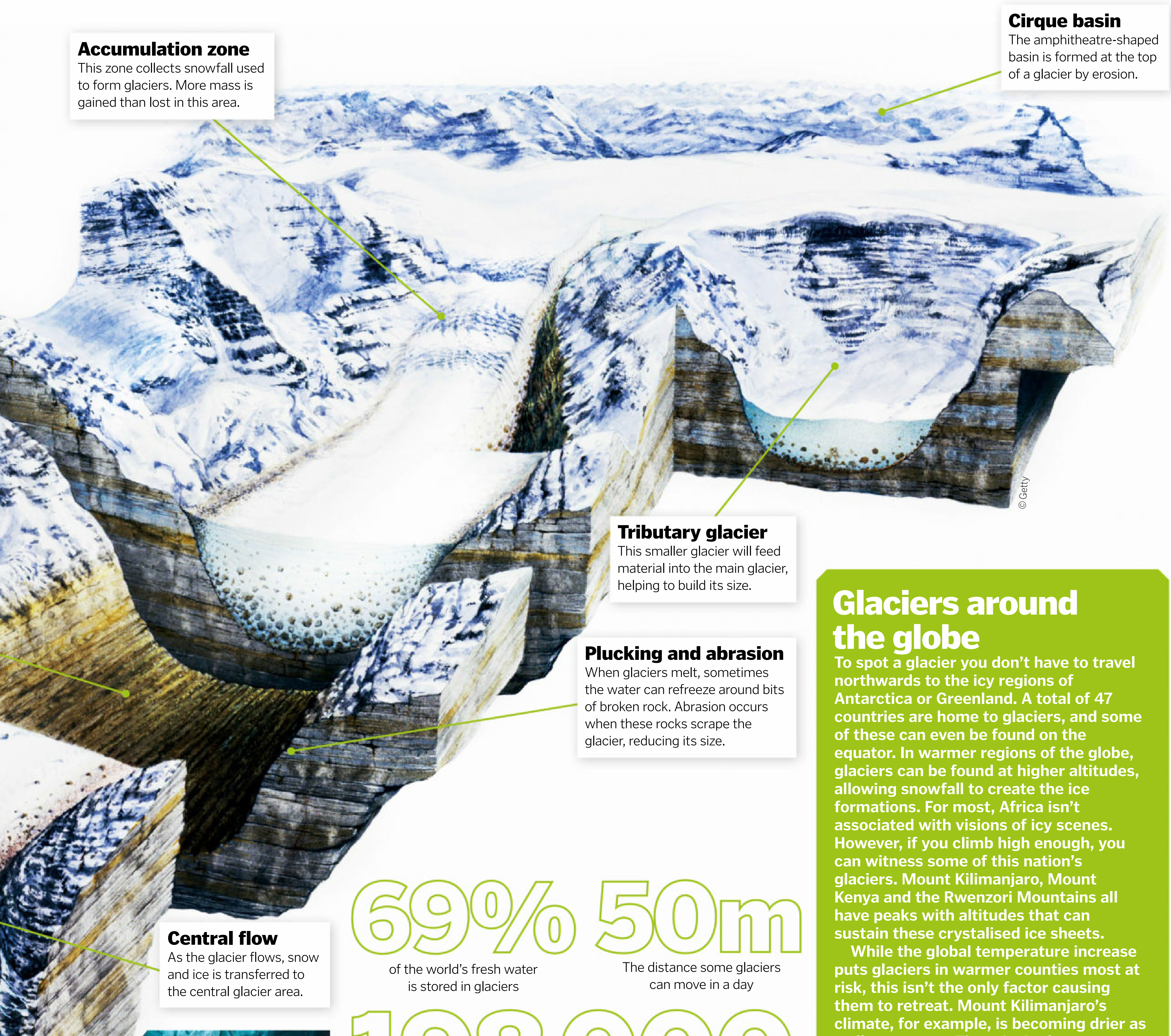
© Getty

Glaciers in the US cover over 75,000 square kilometres

Glacier anatomy

Discover how different sections of glaciers contribute to their changing size






© Getty

Glacial ice appears blue because the compressed snowfall filters out most light wavelengths except blue

69%
of the world's fresh water is stored in glaciers

50m
The distance some glaciers can move in a day

198,000
The estimated number of glaciers currently found on Earth

190km
North America's longest glacier is almost twice as long as the English channel

10%
of the world is covered in glaciers

Glaciers around the globe

To spot a glacier you don't have to travel northwards to the icy regions of Antarctica or Greenland. A total of 47 countries are home to glaciers, and some of these can even be found on the equator. In warmer regions of the globe, glaciers can be found at higher altitudes, allowing snowfall to create the ice formations. For most, Africa isn't associated with visions of icy scenes. However, if you climb high enough, you can witness some of this nation's glaciers. Mount Kilimanjaro, Mount Kenya and the Rwenzori Mountains all have peaks with altitudes that can sustain these crystalised ice sheets.

While the global temperature increase puts glaciers in warmer counties most at risk, this isn't the only factor causing them to retreat. Mount Kilimanjaro's climate, for example, is becoming drier as well as warmer. There isn't always enough moisture in the air to create snowfall at a quick enough rate to replace the melting ice.

Mount Kilimanjaro's glacier has retreated over seven years

The wind superhighway

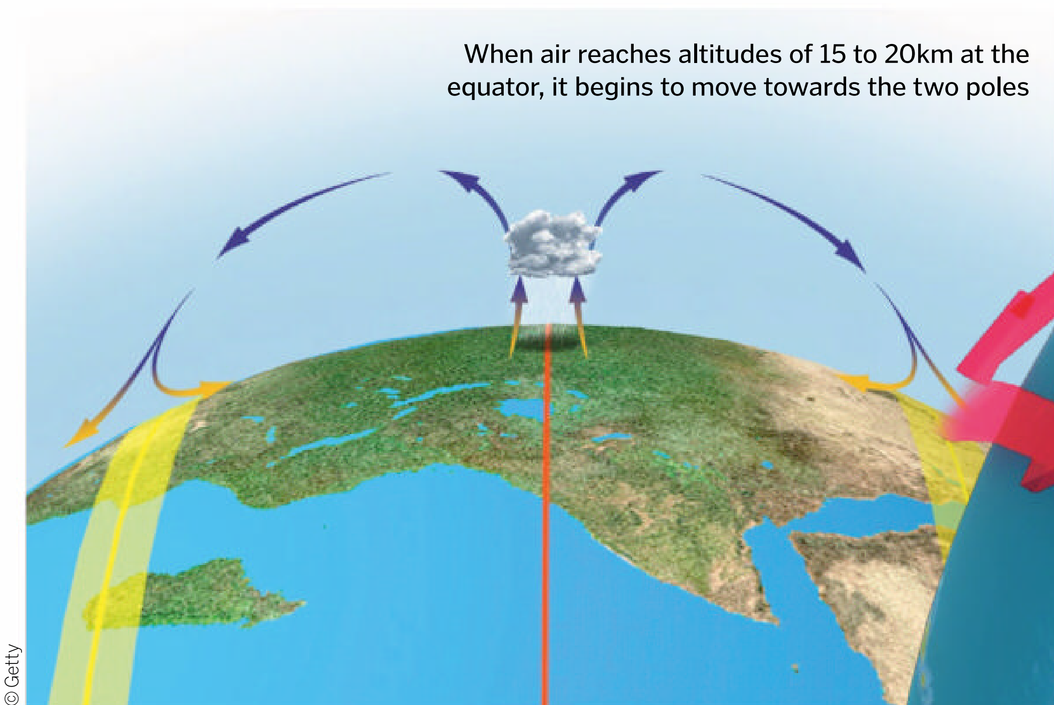
How the atmosphere creates Earth's air currents high in the sky

Air in the atmosphere is constantly on the move. Composed of several layers – from just above ground level to high in the sky – air particles are subjected to varying pressures and energy distribution. Whether in slight movements to carry heat from the equator towards the poles or through strong currents called jet streams, air is on a continuous journey often impossible to see.

Earth's atmosphere is divided into five main layers, with the troposphere lying closest to the surface. Ranging from six to 20 kilometres in thickness, the troposphere consists of two layers: the upper layer, which is known as the free atmosphere, and the lower layer, known as the planetary boundary layer. The bottom layer begins at the Earth's surface and stretches up around 1,000 metres. This may sound like a big space, but it is actually relatively thin. The air moving within the layer can be altered greatly by changing conditions in the landscape and wind-altering pressure above the layer.

Jet streams are usually found in the upper layers of the atmosphere. In the form of thin bands of strong wind, they are created between two air masses of different temperatures. The varying density between masses creates a horizontal pressure difference. Wind tries to flow from high to low pressures, but the planet's rotation forces the air from west to east, flowing around the masses rather than between them. Four main jet streams circulate our planet; two north of the equator and two south of the equator. The ones closest to the centre of the globe are called the subtropical jet streams, and those closest to the poles are the polar jet streams. Occasionally the subtropical and polar jet stream meet, forming a boundary between the two extremely different air masses. This boundary is called the polar front.

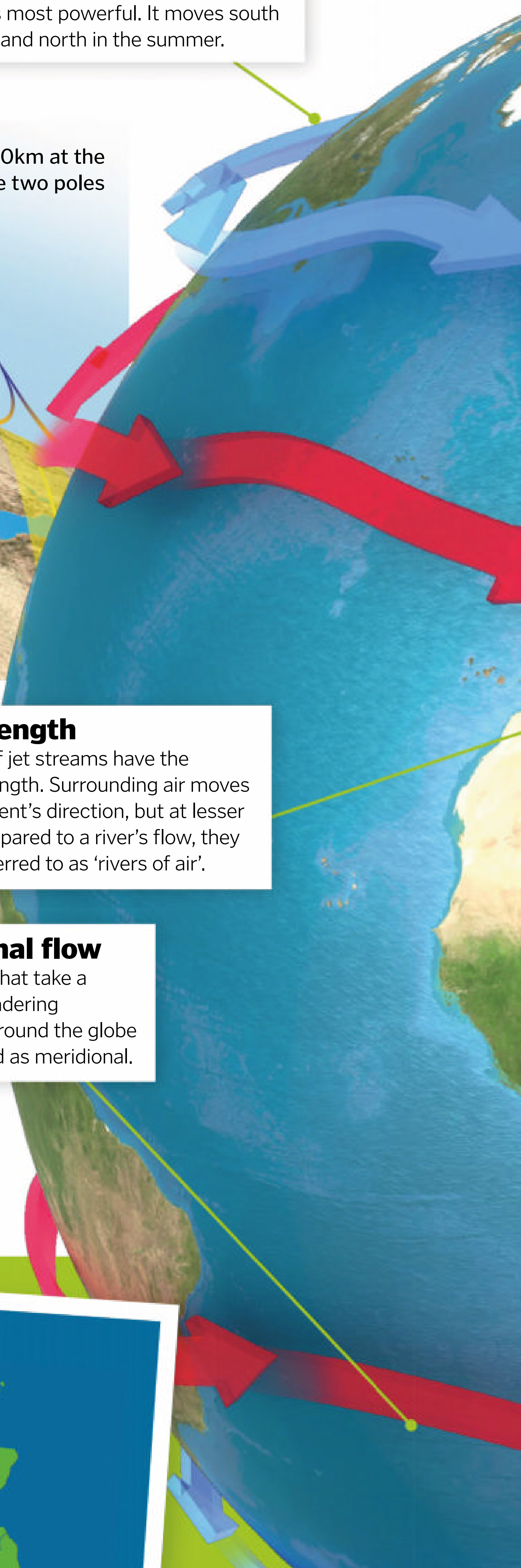
The greater the contrast in temperature across the polar front, the stronger the jet stream. Typically, this is at its strongest during the winter months. The area stores large amounts of potential energy, which is often converted into kinetic energy in the form of extratropical cyclones.



How do air currents move?

Follow the jet streams journeying around the globe

Polar jet stream | Subtropical jet stream



Creating UK climates

The location of jet streams are heavily analysed when predicting incoming weather. In the UK, the position of the polar jet stream determines factors such as where storms will arise. Warm winds that travel over water usually collect some, holding onto it until moving over colder climates, when it condenses into rain. When the polar jet stream is above the country, the weather is usually mild as a result. Contrastingly, if the air current crosses through the land, this is when storms are brought along. Heavy snow is often seen in the south of the UK when the jet streams are carried below the country. Continental Europe gets the majority of the stormy weather in this circumstance, but wind from low-pressure systems heading towards the south pull in the cold air from Europe.

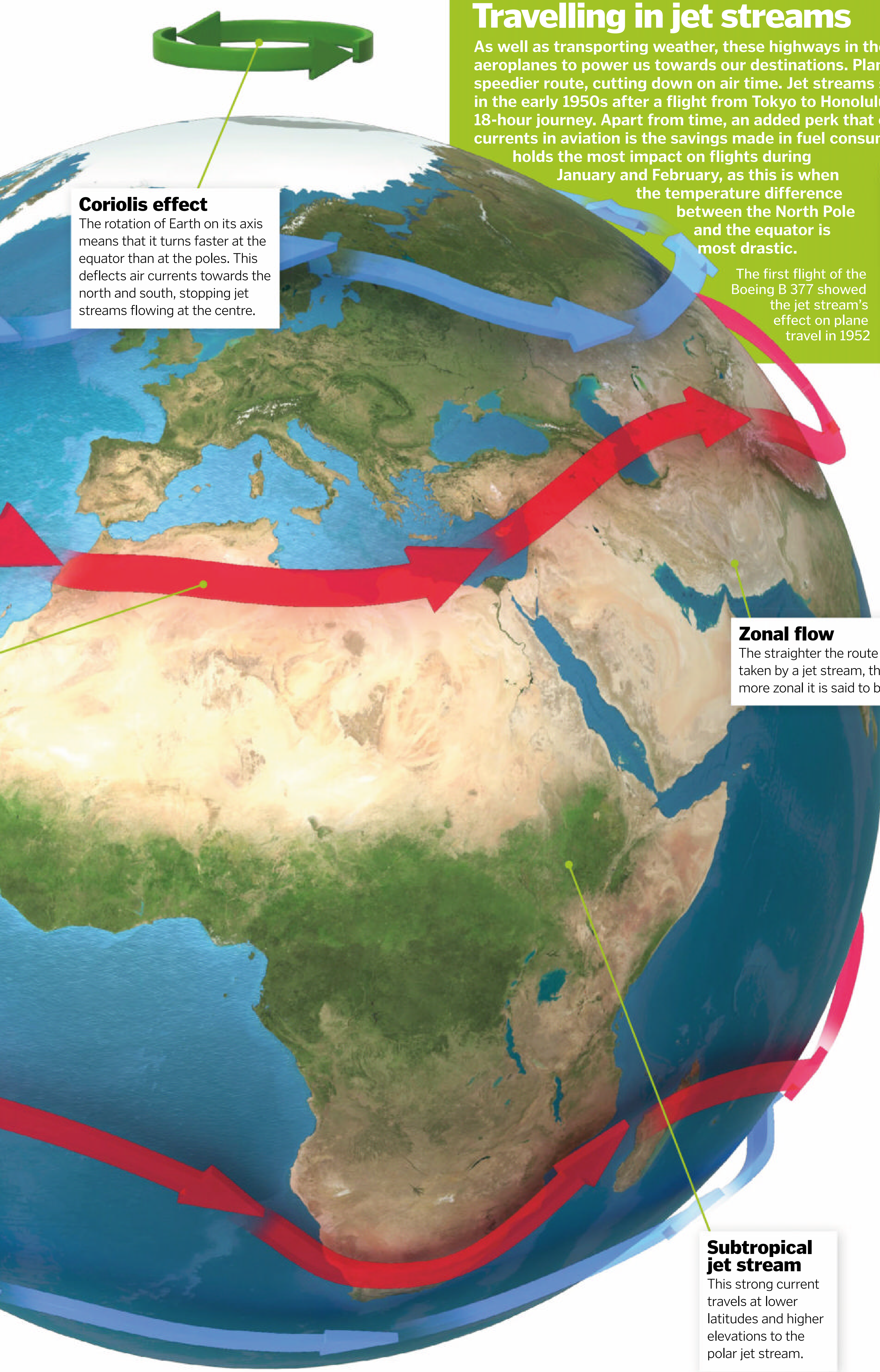
The period of time a weather type will persist is dependant on the type of jet stream in motion. The faster-moving zonal streams will carry air quickly, passing the storm over in a short time. In more meridional currents, the stretched, latitudinal path slows progression, increasing the time taken for the weather front to pass.

When the polar jet stream travels over the UK, weather is wetter and windier than average

Travelling in jet streams

As well as transporting weather, these highways in the sky can be utilised by aeroplanes to power us towards our destinations. Planes often use the streams as a speedier route, cutting down on air time. Jet streams started to be used for air travel in the early 1950s after a flight from Tokyo to Honolulu cut over six hours off the usually 18-hour journey. Apart from time, an added perk that comes with using these natural currents in aviation is the savings made in fuel consumption. The North Atlantic jet stream holds the most impact on flights during January and February, as this is when the temperature difference between the North Pole and the equator is most drastic.

The first flight of the Boeing B 377 showed the jet stream's effect on plane travel in 1952



5 FACTS ABOUT
HOW AIR CURRENTS ALTER THE WEATHER

1 Bringing Britain's rain
The North Atlantic Current, running from the Gulf Stream, results in parts of the UK being warmer than countries to the east on the same longitude. In winter however, it brings more rain, as it directs low pressure towards the UK.

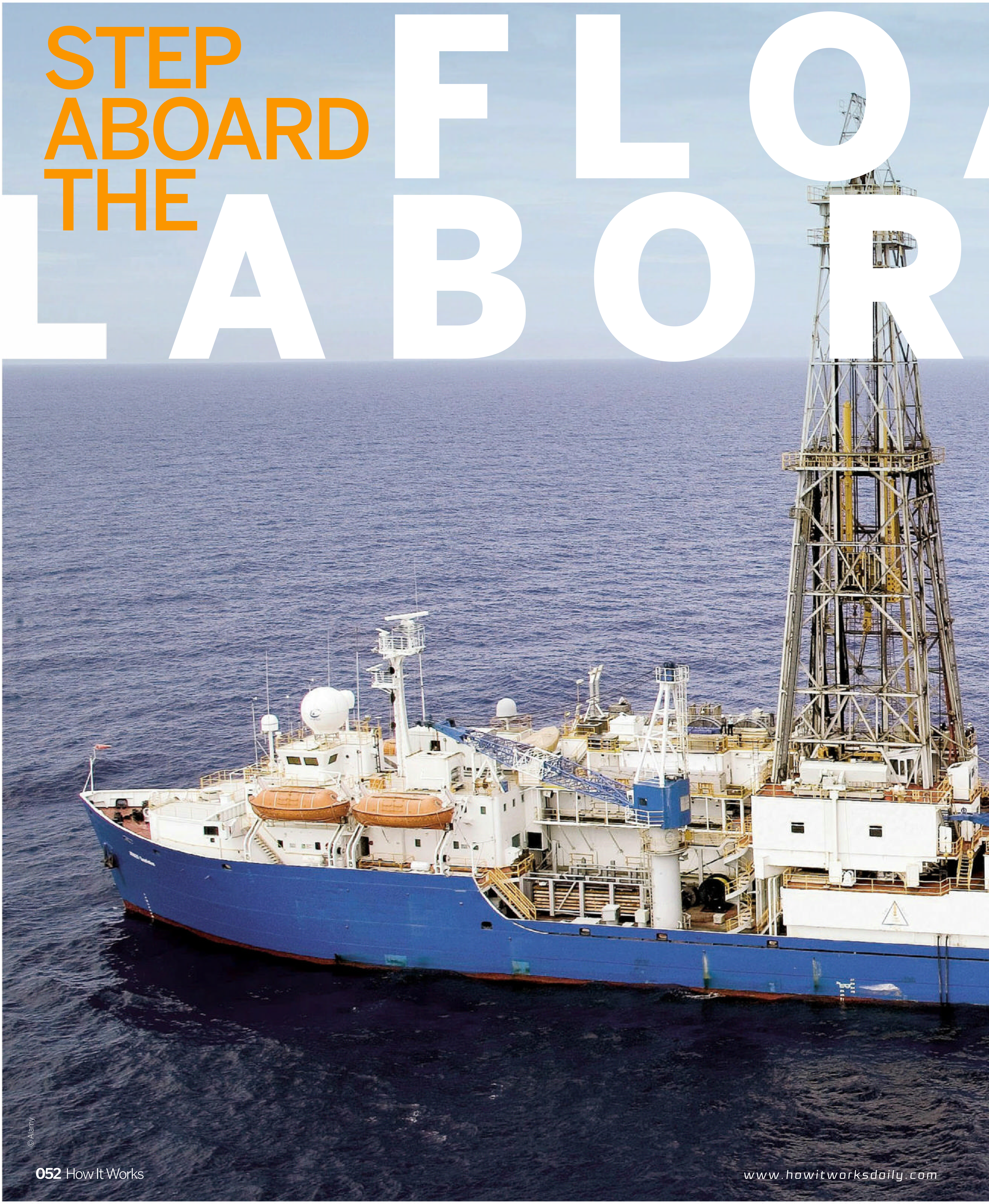
2 Diverting US hurricanes
In autumn, a strong jet stream over the United States carries incoming hurricanes on an eastward path, preventing them from moving north along the Gulf Coast or Atlantic Seaboard.

3 Altering tropical storms
If a jet stream travelling over tropical waters suddenly dips southward, it can cause hurricanes in the area to accelerate in speed, or sometimes tears them completely apart.

4 Creating tornados
Particularly in some North American states, such as Oklahoma, jet streams play a major role in creating super cells, the huge and frequently dramatic storm systems lower in the atmosphere that can lead to the formation of tornados.

5 Drastic temperature drops
As air above jet streams is typically colder than average, when streams take a plunge and move south during winter, freezing conditions form in areas now above the air's path.

STEP ABOARD THE FLO LABOR



© Alamy

ATING
ATORY

The JOIDES Resolution is a science ship that drills holes in the ocean floor to probe the story of the Earth

Words by **Laura Mears**

The history of the Earth is written in the rocks beneath our oceans. Dig down into its layers and you'll find a record of our planet, and its climate, across millions of years. This geological history book could help us to predict our future, but unearthing this remarkable resource is no easy task. Enter the JOIDES (Joint Oceanographic Institutions for Deep Earth Sampling) Resolution.

This formidable vessel is a floating laboratory, measuring 143 metres from bow to stern and weighing 16,000 tonnes. It has a crew of 125 and carries a tower, called a derrick, that reaches 62 metres above the water, beneath which hangs a powerful ocean-going drill. Its job is to bore into the sea floor, retrieving cylinders of sediment called cores. Each one is a vertical slice of Earth's history, with the most recent sediments on the top and the oldest at the bottom.

Powered by a motor on the derrick, the drill can pass through more than 1,600 metres of seabed. It reaches the ocean floor on a string made from hollow nine-metre pipes, joined end-to-end. Each one weighs almost a tonne. As the drill turns, layers of ocean sediments pass into plastic tubes, called core barrels, inside the drill string.

"The drill can pass through 1,600 metres of seabed"

Every time the JOIDES Resolution goes out on an expedition, it has a specific scientific objective to achieve. This often involves drilling down to reach sediments from a particular point in Earth's past. On deck a team of scientists are ready to make sure the ship is on target, and they've got a whole suite of floating labs to help them.

The core barrels travel up through the drill string and onto the catwalk, right outside the

What's in a core?

The sediment cores retrieved by the JOIDES Resolution contain stripes and bands, a bit like the rings of a tree. The layers of rock are made from particles that settled to the bottom of the ocean millions of years ago: clay, sand and silt washed from the land by rivers and rains; fossil shells and faecal pellets belonging to ancient sea creatures; ash and dust from volcanic eruptions; even particles from space, deposited by asteroids.

Each layer records a point in the history of our planet. Examining the sediments can reveal the temperature of the water, the sea level, the direction of the currents, the movements of tectonic plates and even the polarity of Earth's magnetic field.

© Alamy

Sediments from the sea floor contain the fossilised shells of microscopic plankton

core lab. Here technicians clean the plastic barrels and cut them down into 1.5-metre pieces. These pieces then sit in racks inside the lab until they reach room temperature. When they're ready they go through machines that measure their density, magnetism and acoustic velocity – the speed sound travels inside them. This gives the scientists a general idea of what's inside.

Next the team split the cores lengthways: half of the core stays whole so the scientists have a record of where all the parts came from, and the other half is chopped up for further testing. The team need to be quick; as soon as the sediments are exposed to the air they start to change.

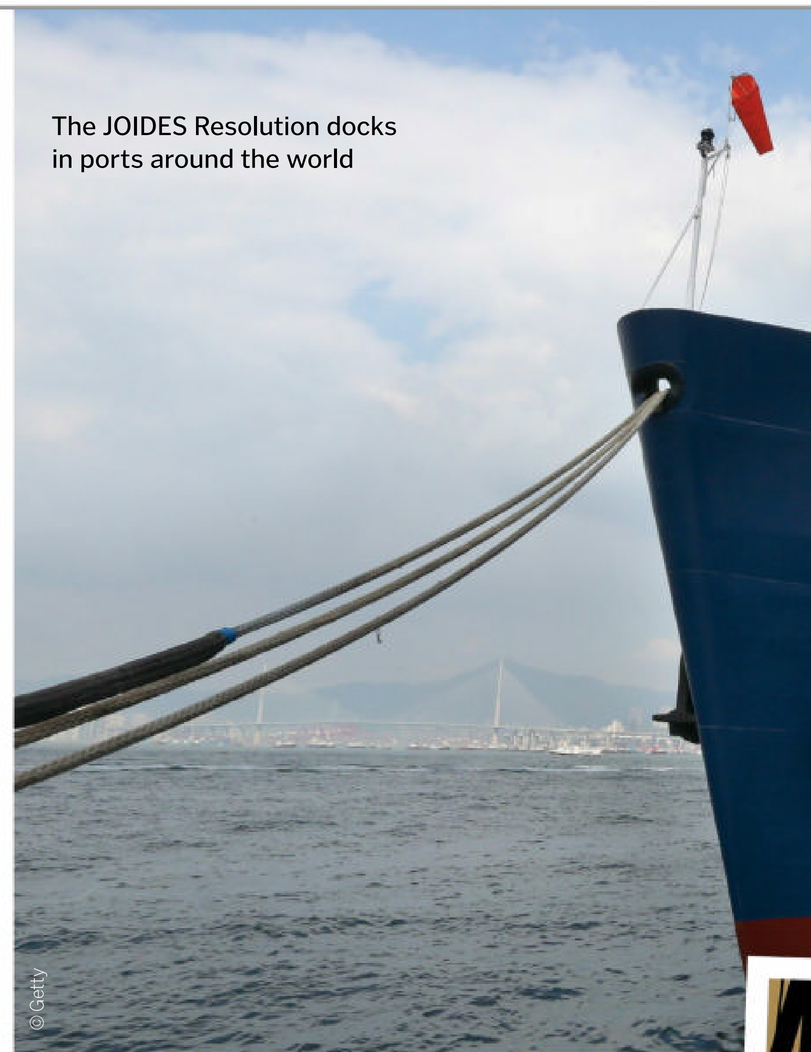
Rock experts called sedimentologists look at the intact half of the core in detail and describe everything they can see. Then stratigraphers and micropalaeontologists get to work on the samples. These fossil scientists specialise in ancient plankton, and the species they see under their microscopes can tell them how old the sediments are.

Chemists also look at the samples, probing for changes to the calcium carbonate from fossil shells and the carbon from living things. This can tell them what has happened to the sediments since they were first deposited. They also perform safety tests to stop the drill team from striking dangerous oil or gas deposits. They look out for chemicals called hydrocarbons – a sign that the drill might be getting close to fossil fuels.

Back on deck when the core collection has finished, the team send instruments down the drill hole, a technique called 'downhole logging'. Sometimes pieces of the core can go missing. Looking back into the hole helps them to line the fragments up, making sure that the record is in the right order.

When an expedition ends the data collected, and the cores themselves, become available for scientists across the world. Kept safe in giant fridges, these precious samples are helping to answer questions about Earth's history, and to predict its future.

> "Core samples are helping to answer questions about Earth's history"



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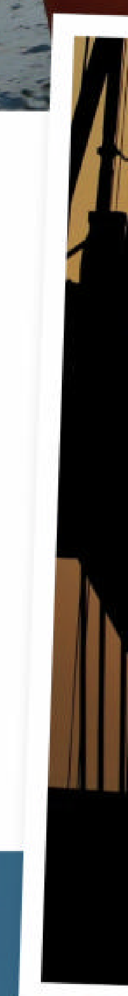
The JOIDES Resolution docks in ports around the world



DISCOVERED BY THE JR

Sediment cores retrieved by the JOIDES Resolution are rewriting the history of planet Earth

© Getty

DINOSAUR DEATH RECORD

When the JR drilled into the crater left by the dinosaur-killing asteroid, the sediments revealed the aftermath of the impact. First there's a layer of glass, then a layer of ash, then all the large plankton fossils disappear.

© Getty

MAMMOTH-KILLING MEGA FLOODS

At the end of the last ice age, melting glaciers triggered waves of catastrophic flooding. Sediments collected by the JR contain the pollen and spores that washed out to sea as water rushed over the land.

© Getty

POLLUTION-MUNCHING MICROBES

Sediments retrieved by the JR contain billions of tiny fossils. JR scientists have also found strange organisms living under the sea floor, including microbes that eat oil and bacteria that make electricity.

© Getty

TREES BURIED AT SEA

JR scientists drilling in the Bay of Bengal found 19-million-year-old wood chips from trees that grew high in the Himalayas. They think melting glaciers tore the mountain plants from the ground and buried them.

Scientists on board the JOIDES Resolution see spectacular sunsets at sea

© Alamy

Q&A

Unearthing ancient plankton

Dr Anieke Brombacher used fossils to work out the age of sediments from Expedition 383

What was EXP383 looking for, and where did you go?

The goal of our expedition was to reconstruct the climate of the oceans around Antarctica over the past ~6 million years. During this time interval, sediments accumulated on an underwater mountain range called the East Pacific Rise. By drilling these sediments and studying their chemical and physical properties we can learn more about the climate in the past.

This part of the Southern Ocean is one of the stormiest regions on Earth and is notorious for its rough seas. The JR can only drill in calm conditions, so our expedition left in winter, which is the calmest season. Even so, we still had some weather issues, including a couple of days with ten-metre waves.

What was your job on board the JR?

I was one of the palaeontologists, whose job it is to figure out the age of the sediments. The oceans contain many kinds of microscopic plankton that get preserved in the sediment. If you find a fossil plankton species that lived between 20 and 15 million years ago, you know that your sediments have to be this old as well. The more species you find, the more accurate the age estimate, so we had four palaeontologists on every shift looking for as many different kinds of fossil plankton as possible. This was an important task because it tells the expedition leaders how much further they have to drill.

What was the most memorable part of your expedition?

For two months, everyone worked towards the same goals, and the team spirit on board was amazing! The most special thing was being able to work with sediments that no one had ever seen before. They had been sitting on the seafloor for millions of years until we drilled them up. I also enjoyed the wildlife. We were visited by an enormous pod of dolphins that swam along with the ship for hours.

© Anieke Brombacher

Dr Anieke Brombacher works within the National Oceanography Centre at the University of Southampton

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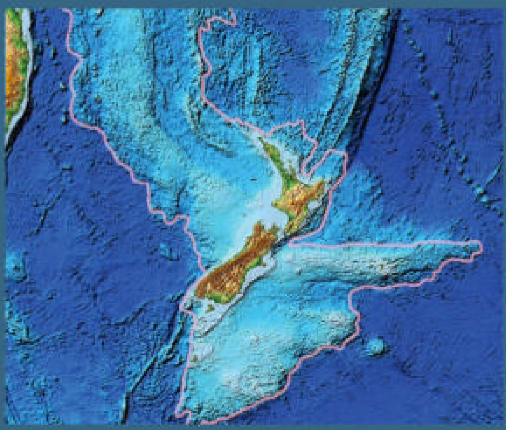
POCKETS OF ANCIENT WATER

The sediments retrieved by the JR are mostly solid, but not always. An Indian Ocean expedition recovered pockets of ancient seawater. These salty bubbles reveal what the sea was like during the last ice age.



Source: Wiki/XXXXXX

A LOST CONTINENT

The lost continent of Zealandia is buried beneath the South Pacific, but it wasn't always underwater. Sediments retrieved by the JR revealed that the seabed folded around 80 million years ago, plunging this forgotten land into the ocean.

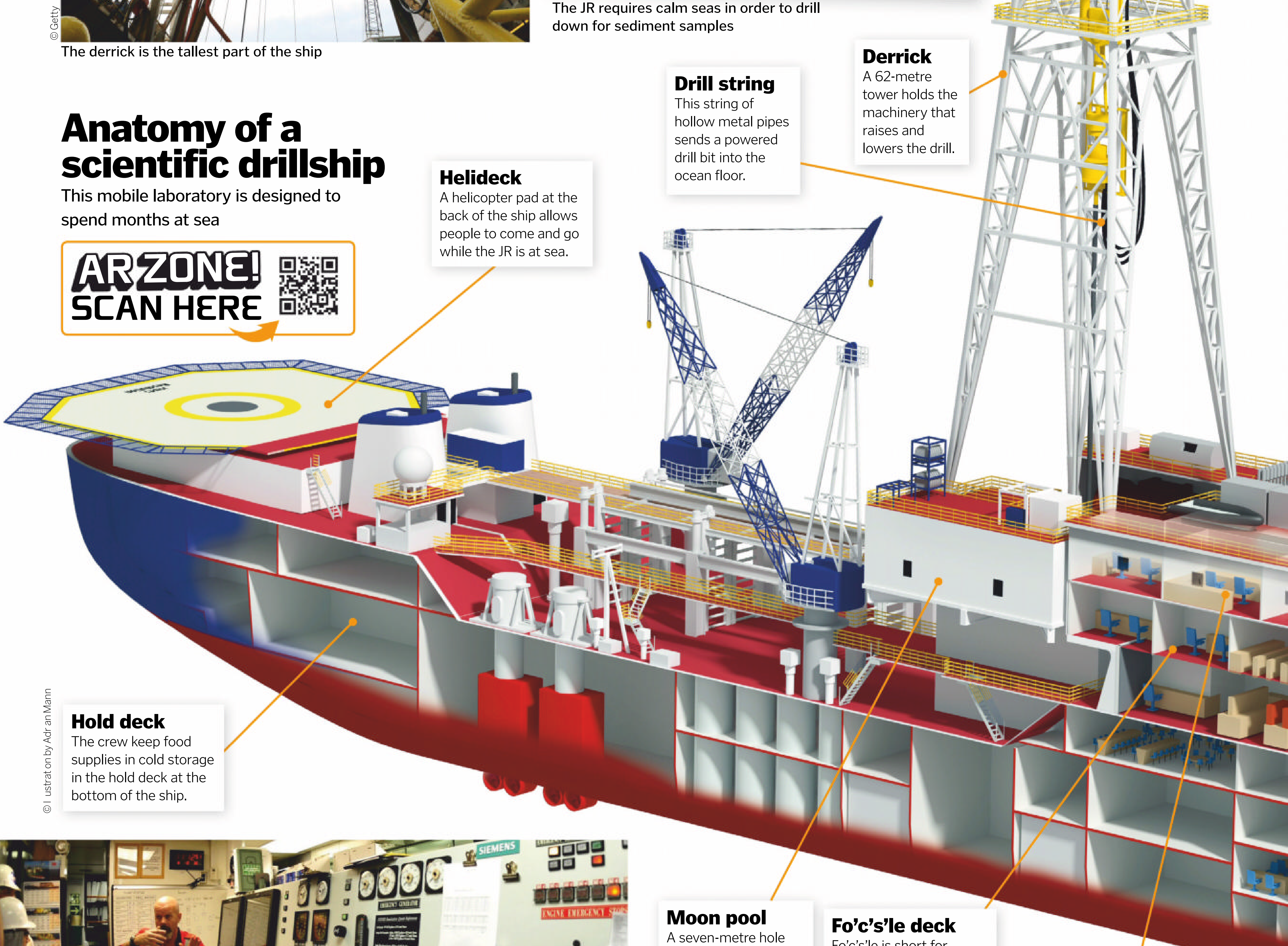
The derrick is the tallest part of the ship

The JR requires calm seas in order to drill down for sediment samples

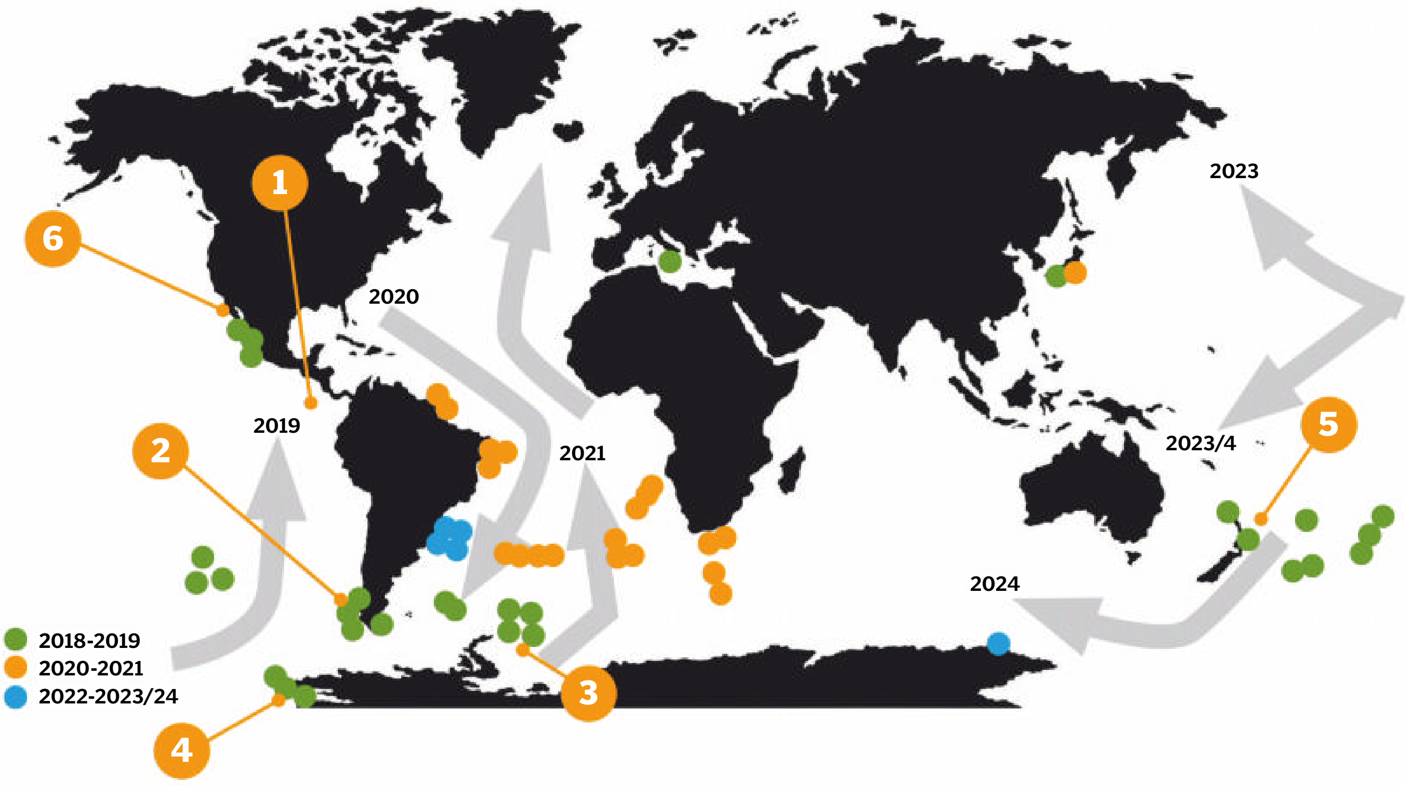
Anatomy of a scientific drillship

This mobile laboratory is designed to spend months at sea

AR ZONE! SCAN HERE



It takes 65 crew members and up to 50 scientists to run each expedition



Recent expeditions

Explore the JR's recent destinations

1 Expedition 385T visited the Panama Basin to examine Earth's crust.

2 Expedition 383 investigated Antarctic currents off the coast of Chile.

3 Expedition 382 explored Iceberg Alley between Chile and Antarctica.

4 Expedition 379 examined the West Antarctic Ice Sheet in the Amundsen Sea.

5 Expedition 376 drilled into an active underwater volcano off New Zealand's coast.

6 Expedition 385 probed plate tectonics in the Guaymas Basin.

Life aboard

Dr Anieke Brombacher spent two months aboard the JOIDES Resolution, living and working in the choppy waters of the Antarctic. "It is very expensive to use the ship for expeditions," she explains, "so you have to do as much work as possible to make it worth the money.

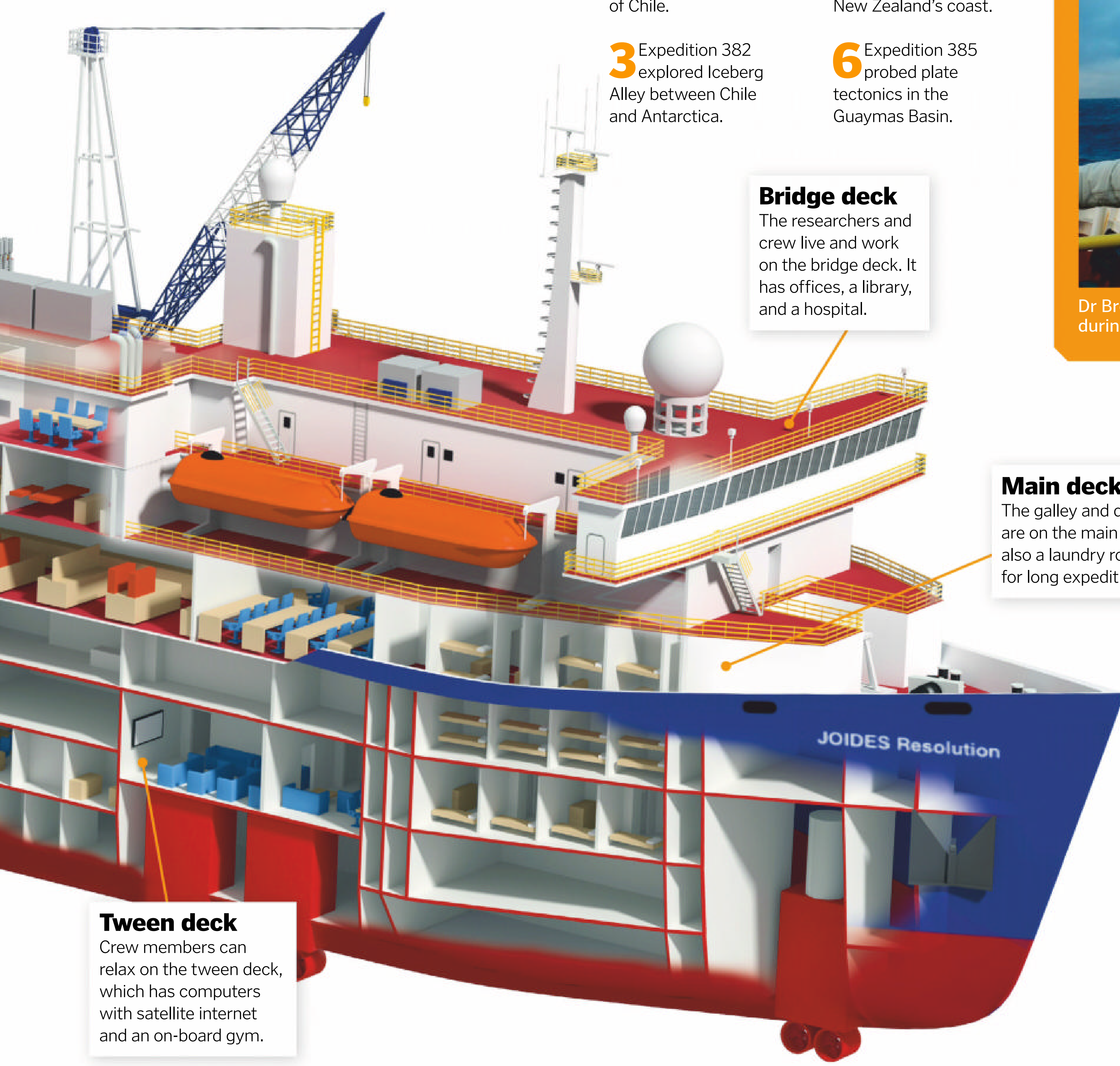
"Everyone works 12 hours a day. I was on the night shift, so my working day started at midnight and ended at noon. Eight weeks of near-darkness can be pretty depressing, but on the upside, we saw the most amazing night skies.

"You usually have an hour or two every day for yourself. There is a small movie room, a coffee corner and a gym to get some exercise. We also had a computer room with internet access through a satellite.

"I really enjoyed going outside for a view of the waves, some fresh air and possibly wildlife. My favourite moment was when a giant fin whale swam past. It was very curious about the ship and swam close by a couple of times while rolling around in the water to get a better view of what was going on."

© Anieke Brombacher

Dr Brombacher experienced some wild weather during her time on the JOIDES Resolution

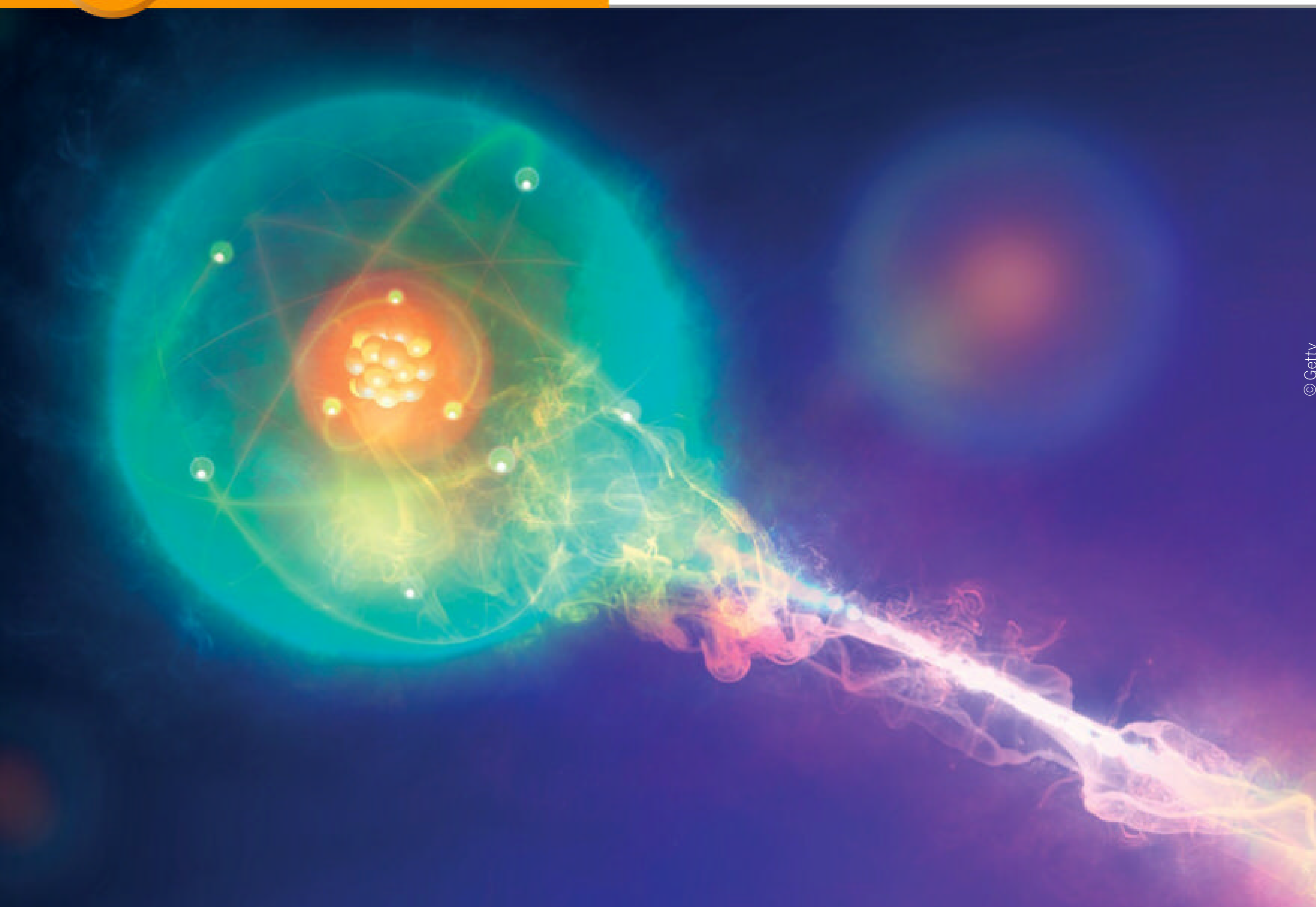


Bridge deck
The researchers and crew live and work on the bridge deck. It has offices, a library, and a hospital.

Main deck
The galley and dining room are on the main deck. There's also a laundry room, essential for long expeditions.

Tween deck
Crew members can relax on the tween deck, which has computers with satellite internet and an on-board gym.

"On deck a team of scientists are ready to make sure the ship is on target"



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Prototype quantum teleportation equipment made by the Institute for Experimental Physics in Vienna in 2002

Teleportation in the real world

The strange phenomenon of quantum entanglement allows scientists to make exact copies of subatomic particles

Words by **Andrew May**

Teleportation is a concept that's familiar to most people, thanks to the fictional 'transporter' in *Star Trek*. As its name suggests, the latter is portrayed simply as another form of transport, getting a person from A to B as quickly as possible. But if you think about it, something much weirder is going on. When someone steps onto the transporter pad, they're completely disintegrated – they cease to exist – and what appears at a remote location isn't the original person, but an exact copy of them. When real-world scientists use the word teleportation, they're just as interested in this copying side of the process as the transport one.

In the everyday world, making a passable copy of an object isn't too difficult. But on the scale of subatomic particles – which is what we're ultimately all made of – things are much harder. This is the world of quantum physics, and pinning down the exact 'quantum state' of a particle is notoriously difficult. The mere act of observing it alters it in an unpredictable way. It's impossible, in fact, to make an accurate measurement of all of a quantum particle's properties. But around 20 years ago scientists discovered that, without even looking at a particle, it's possible to transfer its properties to another particle. That's what they mean by 'quantum teleportation'.

The secret lies in a strange-sounding quantum effect called 'entanglement', by which two separate particles can share a single quantum state – not in the sense that they're both the same, but that knowing something about one tells you something about the other. Their properties are quite literally entangled. In quantum teleportation, the particle to be teleported is brought into contact with one half of a pair of entangled particles. The sender then tells the receiver, who has the other half of the entangled pair – even though they may be on the other side of the world – the result of a simple measurement. This allows the receiver to put their particle into an exact duplicate of the original particle's state – which, as in a *Star Trek* transporter, no longer exists at the sending end.

© Getty

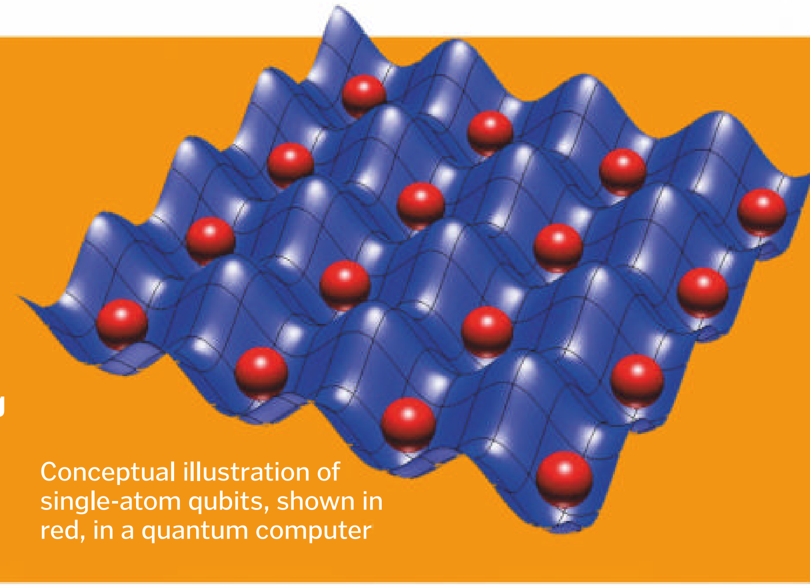
IBM's research director Dario Gil with the Q System One quantum computer

It may sound like an abstract academic exercise, but quantum teleportation offers enormous practical benefits – not as a revolutionary means of transport, like its sci-fi predecessor, but in the world of quantum computing and quantum communications.

Why is teleportation important?

At first sight, being able to copy the quantum state of a particle may not look exciting – but it's hugely significant for the viability of quantum computers. In place of electronic components that are always in one of two states, representing binary digits zero or one, these employ quantum particles that can be in any superposition of these states. The result, called a 'qubit', makes quantum computing much more efficient at number-crunching tasks like code-breaking and equation-solving.

There's a catch though. Qubits, like all quantum states, are destroyed by any attempt to measure them. It's here that teleportation comes to the rescue, by allowing information to be extracted – and even transmitted to distant locations – without disturbing the system. It's an intrinsically secure process, too – because once again you can't observe a quantum particle without changing its state. Trying to eavesdrop on a 'teleported' communication will destroy the message.



Conceptual illustration of single-atom qubits, shown in red, in a quantum computer

Teleporting humans

Despite its much smaller scale, quantum teleportation basically functions like a *Star Trek* transporter. It creates a copy of a particle at a distant location, and erases the original particle's state. Human beings are just large collections of particles, so in theory it should be possible to teleport them too. But there are insurmountable difficulties. The number of particles involved is over 4 tredecillion – four with 42 zeros after it. There's no way to handle that amount of data, quite apart from the technical challenge of creating all those entangled pairs of particles. Even if it was physically possible, the philosopher Derek Parfit has argued that a teleported copy wouldn't be the same as the original person.

Star Trek's transporter is a great sci-fi gimmick, but totally impractical in the real world

5 FACTS ABOUT TELEPORTATION

1 Teleportation's origins
The word 'teleportation' wasn't formally used until the 20th century, although the concept of objects disappearing from one place and appearing in the other has been documented since 1878.

2 Einstein called entanglement "spooky"
Not because he found it scary – he just didn't believe in it. He said "physics should represent a reality in time and space, free from spooky action at a distance".

3 The Aspect experiment
Proof that entanglement is real came in the early 1980s with a groundbreaking experimental demonstration by French physicist Alain Aspect.

4 Mainstream use
The word 'teleportation' was first used in a serious scientific context in 1993 in a theoretical paper written by Charles Bennett and his team.

5 Long-distance teleportation
In June 2017, Chinese scientists teleported a quantum state from a ground-based lab to a satellite in orbit, 300 miles away.

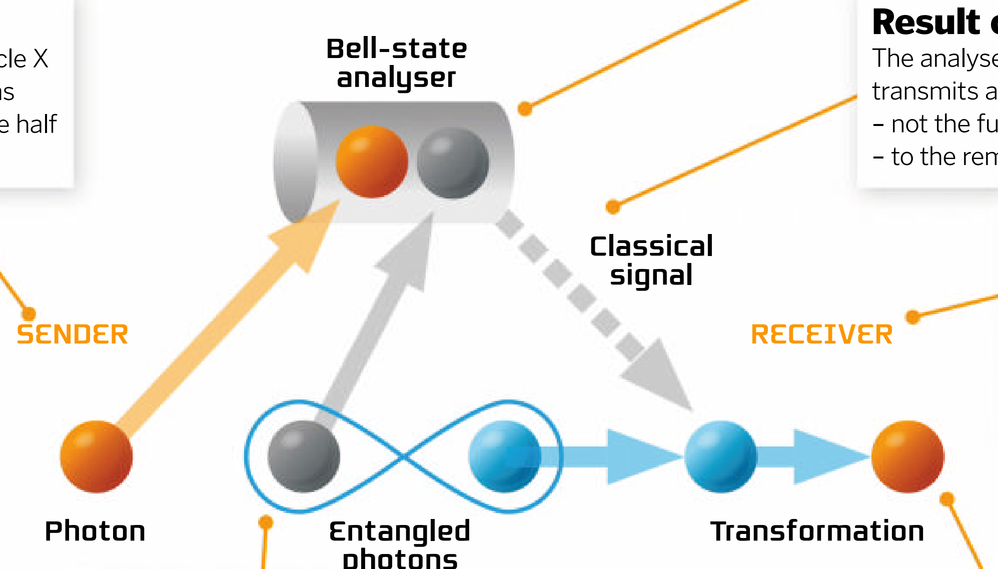
How quantum teleportation works

An exact copy of the particle being teleported appears at the receiving end

Quantum state analyser
The sender puts X, the particle to be teleported, into this gadget with their half of the entangled pair, A.

Sender
The sender has particle X – to be teleported – as well as particle A, one half of an entangled pair.

Result of analysis
The analyser equipment transmits a single number – not the full quantum state – to the remote receiver.

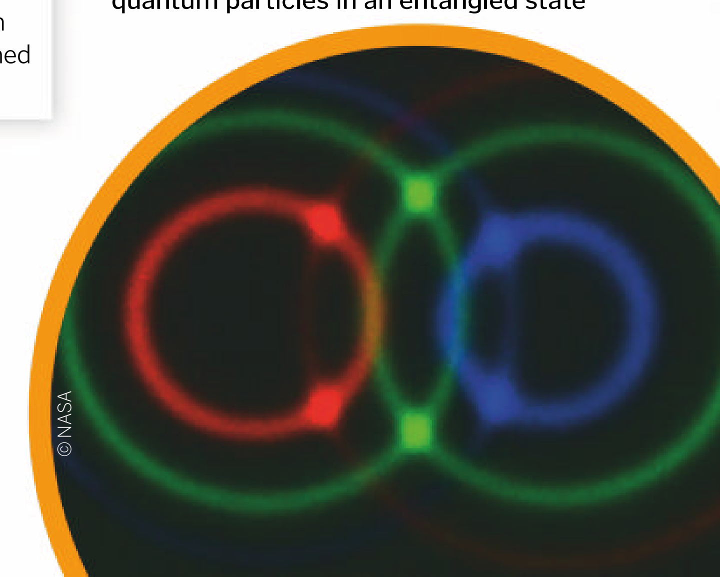


Receiver
The receiver has the other entangled particle, B, which will be transformed into a copy of X.

Entangled particle pair
The key to teleportation is the fact that A and B, although widely separated, are in a shared quantum state.

Making a copy
The receiver uses the number provided by the analyser to transform particle B into an exact copy of X.

Symbolic representation of a pair of quantum particles in an entangled state



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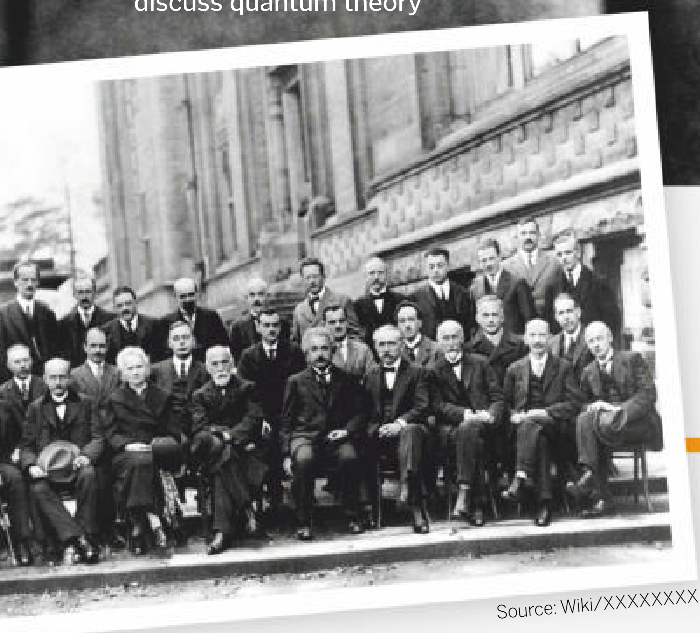
THE BIG IDEA

What was the point behind the cat?

Through his thought experiment, in which the contained cat could be dead or alive, Schrödinger was presenting a principle of quantum mechanics in a way most people could comprehend. He wanted to make people understand the flaws in quantum superposition when taken out of general equations and placed in real-world scenarios. The theory states that objects in a tangible system can exist physically in all possible forms until proven otherwise. Schrödinger applied this concept to his cat interpretation to explain its unrealistic actuality. He believed that while the outcome was a logical one, elements of it were also irrational.

Schrödinger showed how misinterpreting quantum theory – in evaluating objects to be in two states rather than two possibilities – isn't justifiable when realistically there is only one actuality. He allowed people to visualise that only one outcome can be taking place – even when no one is there to observe.

Schrödinger (back middle, sixth from left) stands with some of the world's most famous physicists at the 1927 Solvay Conference to discuss quantum theory



Source: Wiki/XXXXXXXX

A life's work

The story of Schrödinger

1887
Erwin Rudolf Josef Alexander Schrödinger is born on 12 August in Vienna, Austria.

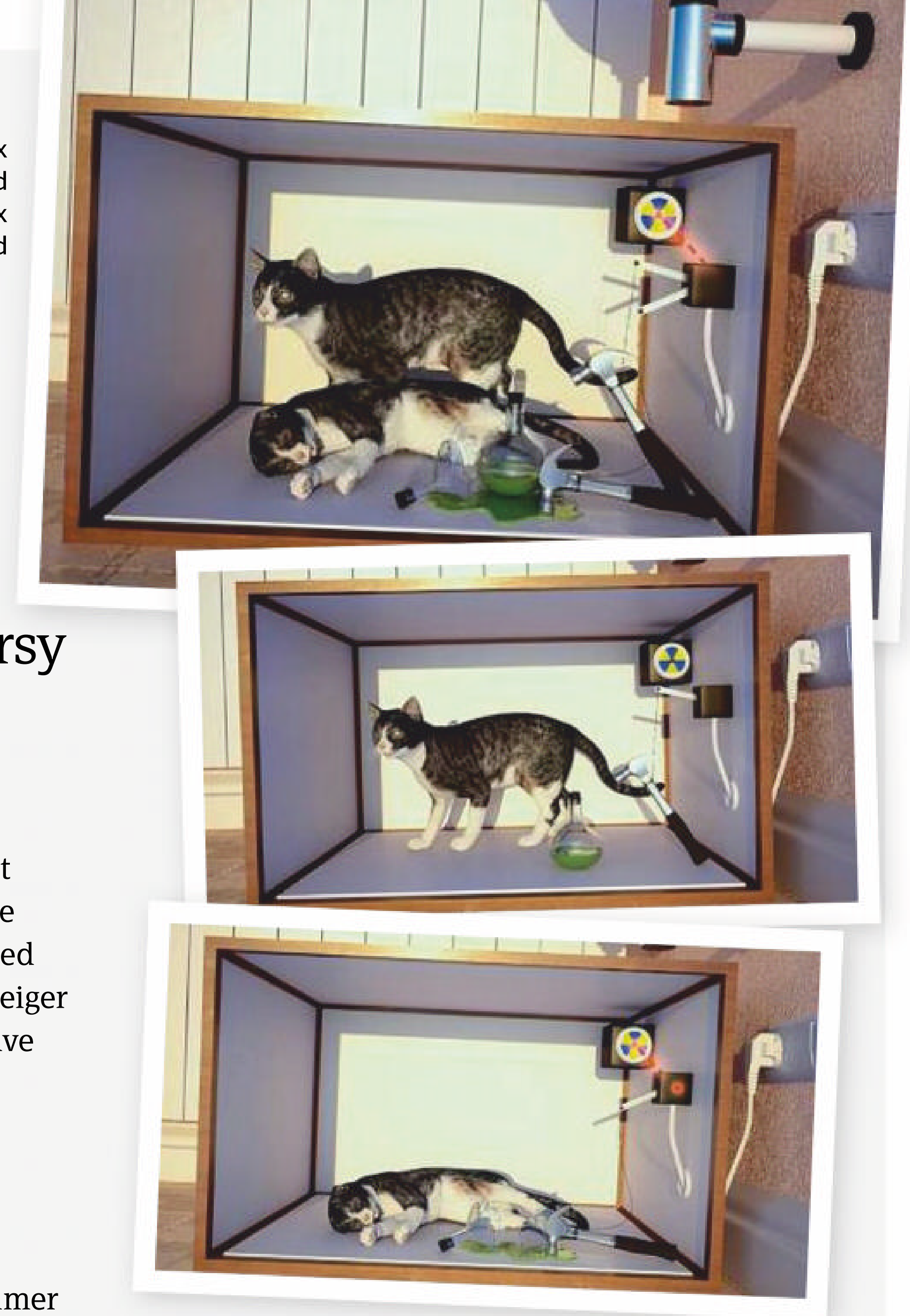
1898
Schrödinger is educated by a private tutor until he is 11 years old.

1910
Erwin graduates with a PhD in physics, aged 23.

1914
He serves as an artillery officer in Italy during World War I.

1921
Schrödinger joins the University of Zurich as a professor. Here he came across a proposed wave mechanics theory which sparked his interest in electron movement.

1926
His famous discovery about wave function in quantum mechanics is made, creating the Schrödinger equation.



The cat in the box is both alive and dead until the box is opened

Erwin Schrödinger

Introducing the influential physicist whose cat controversy made waves across the science community

When you think about Austrian physicist Erwin Schrödinger, your mind may first turn to his famous thought experiment surrounding a poisoned cat in a box. However, as part of his contributions to quantum mechanics, he is often most celebrated for devising the 'Schrödinger equation'.

During the 1920s, the field of quantum mechanics emerged, along with a race involving all the top scientists to find ways to describe and explain the motion of some of the smallest building blocks of the universe. Schrödinger's scientific capabilities had evolved through studying and working at multiple top universities alongside the likes of Albert Einstein. It was while he was working as a professor at the University of Zurich that he delved deep into the research of theoretical physics, allowing him to piece together some of the most important models of his career.

The first of his major breakthroughs came when he began studying the different energy states of electrons in an atom. Using a previous hypothesis that particles in an atom move in waves – similar to the movement of light waves – Schrödinger was the first person to organise data into an equation to prove how this happened. The equation is often compared to Newton's law of motion in its level of importance to quantum mechanics.

Used across physics and chemistry, Schrödinger's equation is used to deal with any issues regarding atomic structure, such as where in an atom electron waves are found. Additionally, his wave equation demonstrated superposition: a state that includes all possible solutions. Because his equation was linear and had more than two changeable factors, it created a range of possible outcomes.

Revolutionising the way quantum mechanics was visualised, Schrödinger focused again on superposition in his most renowned thought experiment. For this, he asked people to imagine a cat inside a sealed container. Trapped alongside the cat is a Geiger counter, poison, a hammer and a radioactive substance. In this situation, due to the random process in which the radioactive substance will decay, there is no way of knowing when this will happen. When it does, the activity will be detected by the Geiger counter, which will trigger the hammer to release the poison and eventually lead to the death of the cat.

As this process cannot be seen, the cat can't be definitively pronounced dead or alive. For this reason, Schrödinger explained that it must be assumed that the cat is in two states – living and deceased – until the box is opened and its contents revealed.

Later on in his life, Schrödinger went on to publish academic books and journals. In one of his most well-known, called *What is Life?*, he used his expertise in quantum physics to delve into the world of biology and explore how his findings could explain the stability of genetic structure. While later developments and research in this area have led to adaptations of his findings, his work still holds great use in introducing students to quantum mechanics.

Across the board of Schrödinger's experiments, thought processes and scientific writing, he is one of the highest regarded physicists of his time. Acknowledged during his life through prestigious awards and general science development, his studies continue to influence the worlds of both science and philosophy to this day.

FIVE LEGENDS ABOUT... ERWIN SCHRÖDINGER

1 Sanatorium study
His thesis for the Schrödinger equation was written while in a sanatorium, being treated for tuberculosis. Giving him grief for much of his life, it also provided extensive study time.

2 Friendly rivalry
Einstein was unable to accept the use of random acts to define science, such as in the Schrödinger's cat experiment, and is famously quoted saying: "I can't believe God plays dice."

3 Inspiring others
Schrödinger inspired Watson and Crick, credited for their discovery of the structure of DNA. They both named his book, *What is Life?*, in creating their interest in cellular biology.

4 Man on the Moon
A Moon crater was named after him. Found on the far side of the Moon near the lunar south pole, the Schrödinger crater is the best-preserved impact basin of its kind.

5 Working through the great war
While serving as an artillery officer with the Austro-Hungarian forces in World War I, Schrödinger still found the time to study papers written by Albert Einstein.

1927
Schrödinger moves to Berlin for a new position at the University of Berlin.

1933
Schrödinger wins the Nobel prize for his work in quantum theory.

1937
Schrödinger wins the Max Planck medal; the highest award of the German Physical Society.

1950s
He studies theoretical physics in Dublin, Ireland, after being invited by Irish Prime Minister Éamon de Valera.

1955
While working as director of the School for Theoretical Physics, Schrödinger produced many research papers and books, including *What is Life?*.

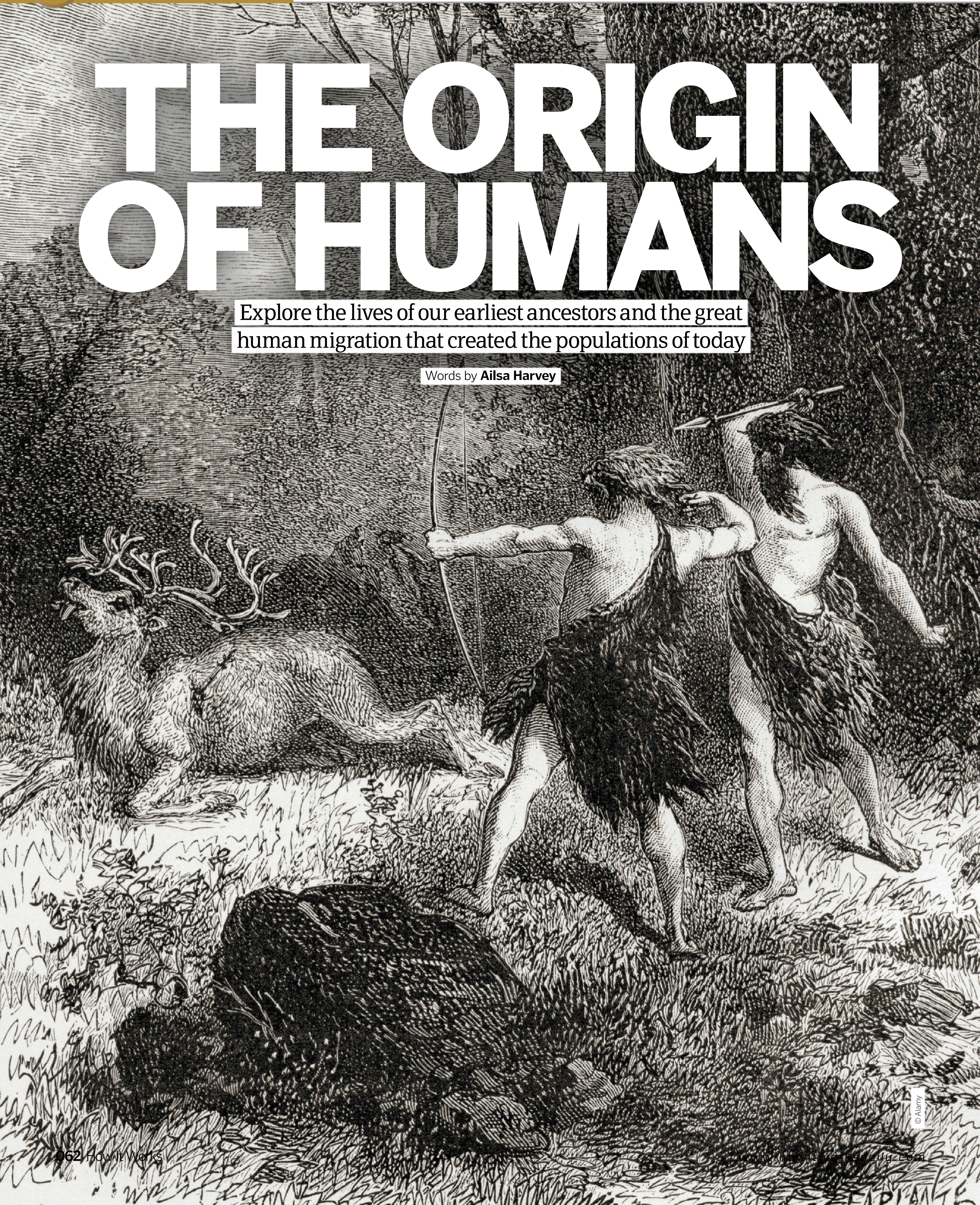
1961
Back in his hometown, Erwin Schrödinger dies of tuberculosis on 4 January in Vienna, aged 73.

"Schrödinger went on to publish academic journals"

THE ORIGIN OF HUMANS

Explore the lives of our earliest ancestors and the great human migration that created the populations of today

Words by **Ailsa Harvey**



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How did we get here? For most of our lives we have some control over what we do and where we go. But the movements and decisions made by those who came thousands of years before us have shaped the evolution of the species we were born into. As a result of early migration, there is now little land on our planet not inhabited by humans. Evolving to suit each location has created differences in our appearance, behaviour and culture.

If you were to jump back in time around 200,000 years, this wouldn't be the case. Despite our differences, every one of us can be traced back to a single population. While other similar human-like species lived on different continents – such as *Homo neanderthalensis* in Europe and *Homo floresiensis* in Asia – our ancestors, the archaic *Homo sapiens* are thought to have come from Africa. As the place where humans first evolved, it is also where our species has spent the majority of its time.

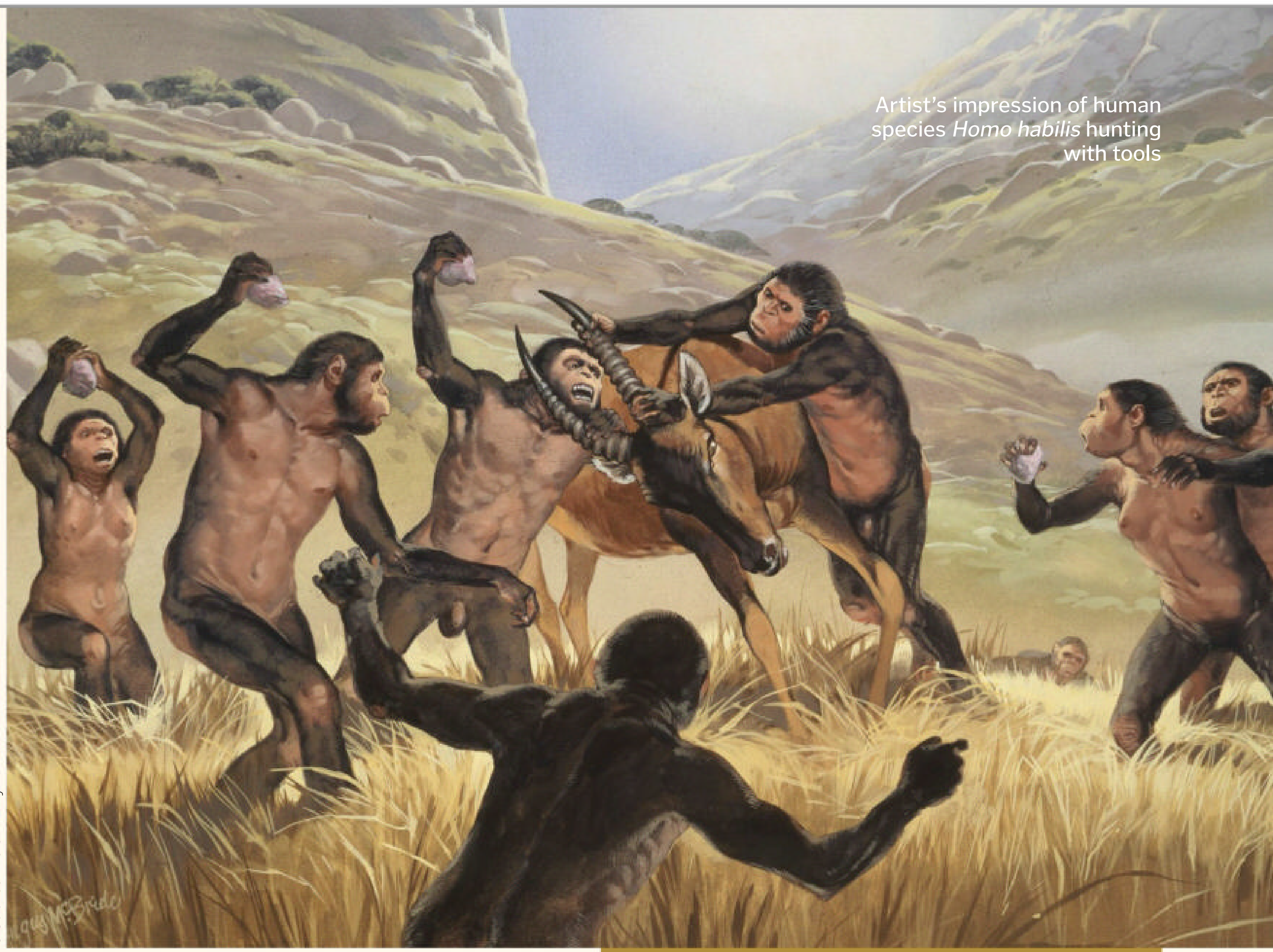
In a land where lions, elephants and wildebeest roamed, early humans were in a constant battle for survival. Some sites, such as Lake Victoria in Kenya, display the animal bones of the dinners they hunted, but their lives weren't easy, with competing carnivores and constant threat from every quarter. Biological studies have linked the evolution of our ancestors, from adopting larger brains to an increase in high-protein diets. Experts think an increase in hunting, as well as the potential of the African landscape to provide high-protein wetland ferns, crustaceans and snails would have contributed to this gradual change.

When the time came for the population to explore other areas, successful migration overseas was made possible by lower sea levels caused by an ice age. The gap between continents was reduced so much so that early humans attempted – and succeeded – to cross. This was likely in the search for suitable food sources, a better climate and space. Humans reached far-away lands, further colonising areas and allowing *Homo sapiens* to expand.

But how are we able to follow and understand this journey that was taken so long ago? Despite the time that has passed, ancient humans left traces of the paths they took: themselves. Studying remains of their bodies, as well as man-made tools and insightful artwork, we are able to understand something of the lives and movements of our ancient ancestors.

As well as providing awareness into successful new settlements, skeletal remains have also played a part in demonstrating many failed attempts at leaving the original homeland. A wave of earlier migrators appears to have paid the ultimate price by trying to leave Africa via the Sahara Desert. When drought returned to the area, resources were scarce and they were left to perish in the dangerously dry lands.

For those that made it out of Africa, they would probably have encountered human-like relatives with different features to *Homo sapiens*. There were nine known 'human species' who roamed the Earth around 300,000 years ago. So how did these variations condense to just the one we have today? Early *Homo sapiens* encountered one of these species in Europe. *Homo neanderthalensis*, otherwise known as the Neanderthals, roamed this area but, as with the other seven species, within a few thousand years of human migration out of Africa, Neanderthals became extinct. Traces of their DNA are carried in many Eurasian people today, proving that our early human ancestors didn't just compete and replace – they also mated, giving rise to new human characteristics.



Artist's impression of human species *Homo habilis* hunting with tools

A simple life

The early humans of Africa lived a life much simpler than ours today. Using the resources available to them, they were able to make tools to hunt, find shelter, start fires and cook food. Using resin from trees almost like a glue, there is evidence of the production of wooden handles and stone knives being whittled together. African settlers are thought to have had an intricate knowledge of the land's plants to use to their advantage.

There are still some people living in the same region who follow a lifestyle not dissimilar to theirs today. The Bushmen in Southern Africa have continued the early hunter-gatherer lifestyle. With open land and available wild food sources limited in today's society, this lifestyle has become far more difficult than the natural ways of those who lived hundreds of thousands of years ago.

Humans' homeland

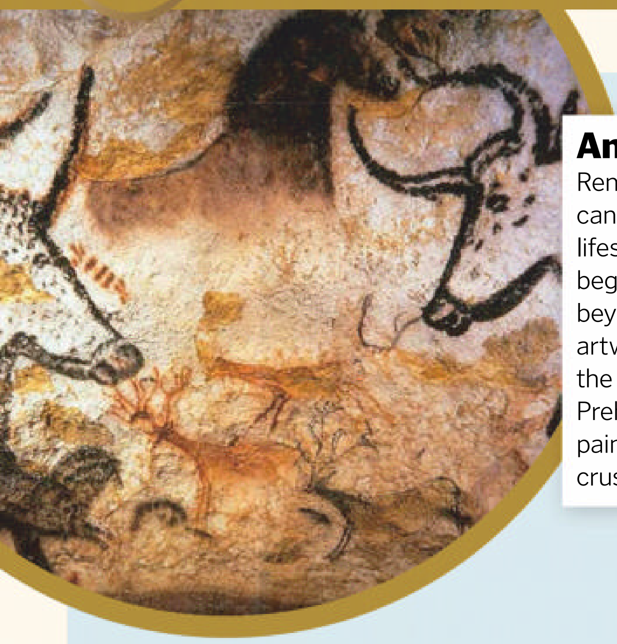
Recent research involving the study of 1,217 samples of mitochondrial DNA of those living in South Africa has pinpointed a specific area as the origin of humans. Today, if you visit this region of Botswana, just south of the Zambezi River, the land is covered in salt flats. But thousands of years ago, the environment was the perfect habitat for early *Homo sapiens*. In place of the salty, dry plains lay a great lake, holding freshwater that some of the first members of our species could have depended on.

Lake Makgadikgadi and its surrounding land would have been a lush homeland. This body of water existed from 2 million years ago until around 10,000 years ago, covering anywhere from 80,000 to 275,000 square kilometres. This region around the river may have supported human settlement until Africa's rain belt eventually began to shift.

Salt pans in Makgadikgadi are all that remain of the luscious land

The great human migration

Follow the path of our ancestors as they populated the world



Estimated to be 20,000 years old, cave paintings in Lascaux mainly depict large local animals

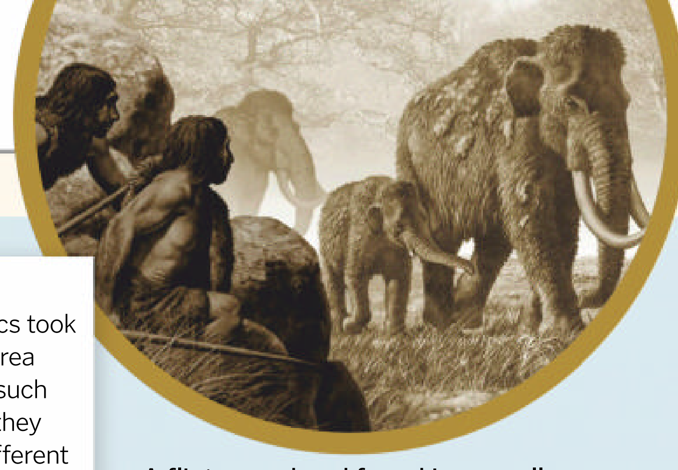
Source: Wiki/Prof saxx

Ancient artwork

Remnants of our ancestors' artwork can portray aspects of their lifestyles, showing signs of humans beginning to focus on thoughts beyond survival. The famous animal artwork in Lascaux, France, marks the beginning of figurative art. Prehistoric art was created using paints comprised of ochre, charcoal, crushed seal bone and rock chips.

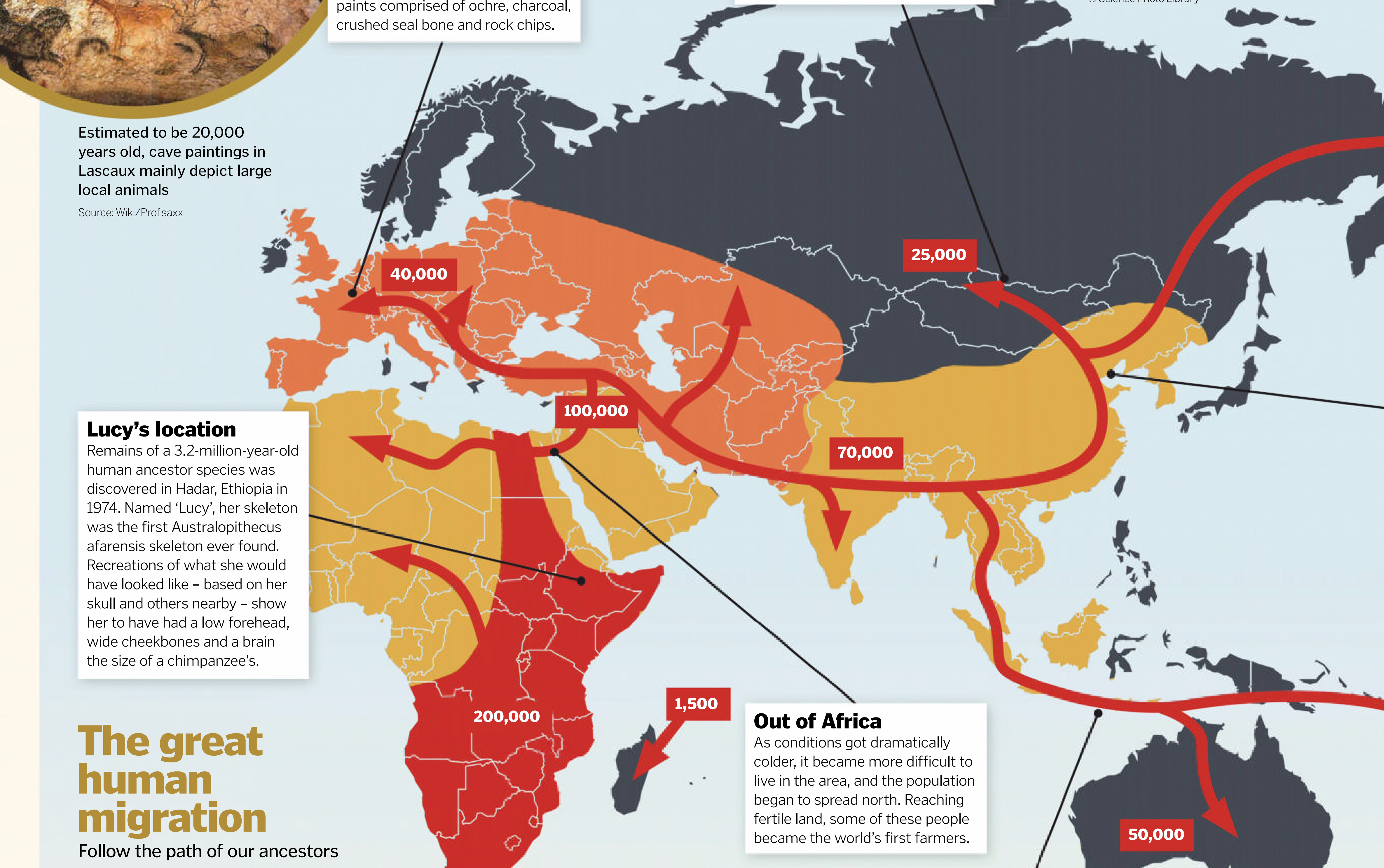
Inland diversion

Migration away from the tropics took humans to Central Asia. This area suited hunters of megafauna, such as woolly mammoths, before they became extinct. From here, different migration patterns saw the species split in a major spread, heading for different reaches of the globe.



A flint arrowhead found in a woolly mammoth bone is evidence of humans' role in their hunting

© Science Photo Library

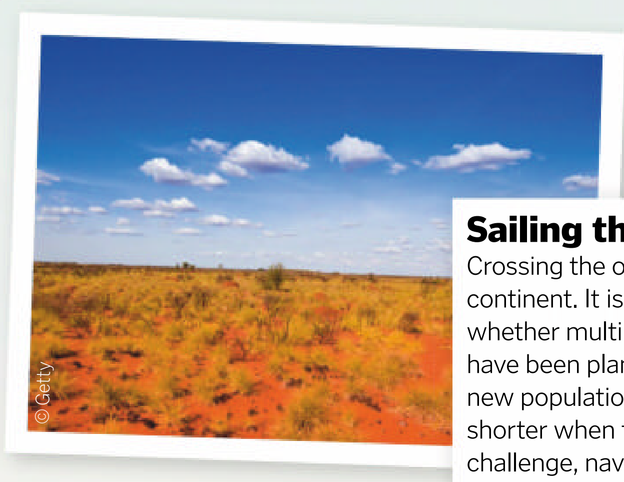


Lucy's location

Remains of a 3.2-million-year-old human ancestor species was discovered in Hadar, Ethiopia in 1974. Named 'Lucy', her skeleton was the first Australopithecus afarensis skeleton ever found. Recreations of what she would have looked like – based on her skull and others nearby – show her to have had a low forehead, wide cheekbones and a brain the size of a chimpanzee's.

Out of Africa

As conditions got dramatically colder, it became more difficult to live in the area, and the population began to spread north. Reaching fertile land, some of these people became the world's first farmers.



After sea levels rose, humans living in Australia evolved and adapted to the unique land and ecosystem

Sailing the seas

Crossing the ocean from Asia to Australia, humans discovered a large new continent. It is unclear whether humans crossed in one planned wave or whether multiple trips were made over time, but the journey is thought to have been planned in order to result in enough people on the island to keep a new population going. While the area of ocean separating the lands was shorter when this migration occurred, the journey would still have come as a challenge, navigating large stretches of water on their handmade boats.

Human timeline

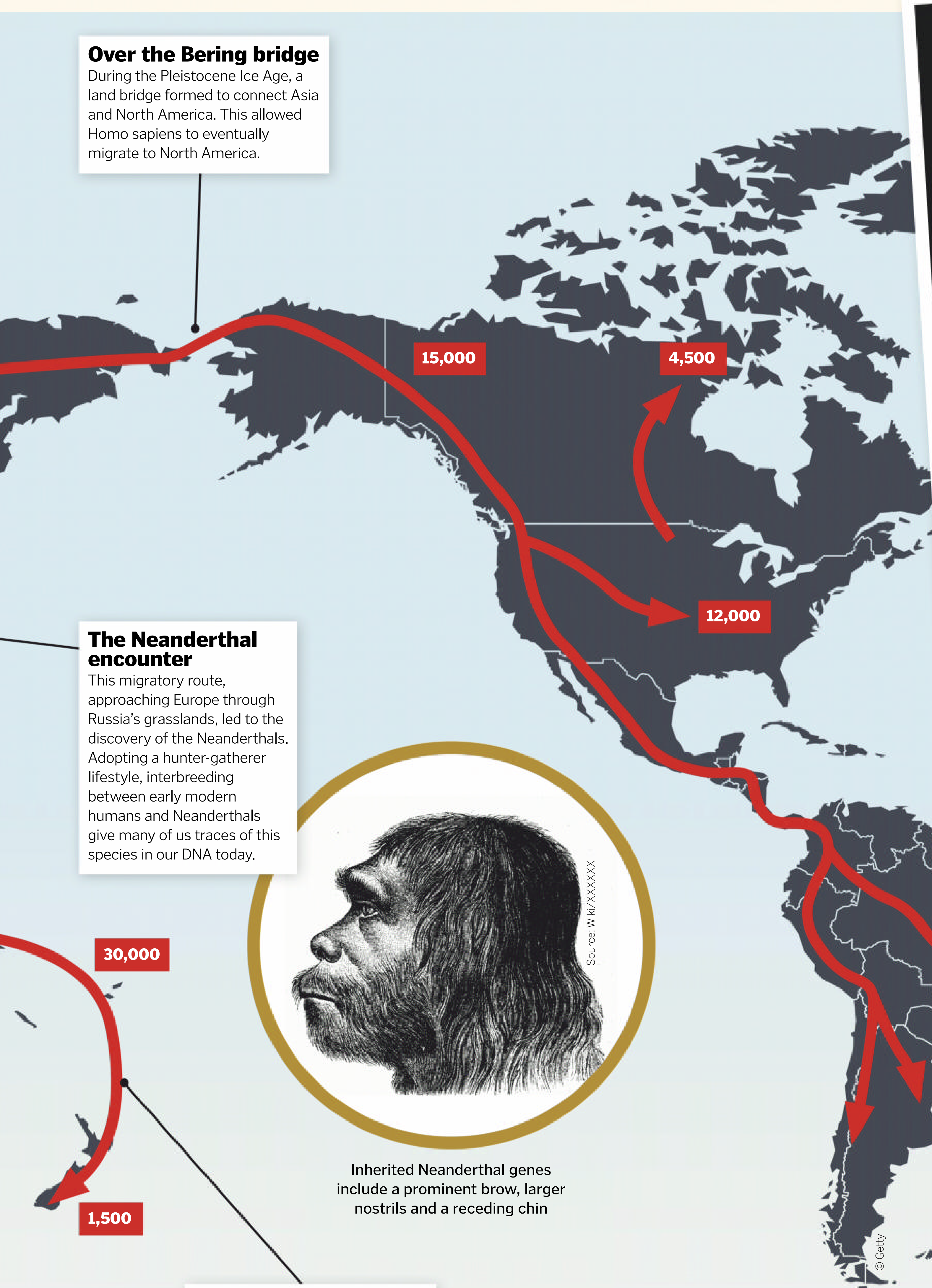
The global spread of humans was gradual

300,000-200,000 years ago
Homo sapiens (modern humans) appeared in Africa.

Around 70,000 years ago
Prior to migration, major climatic shifts may have caused the human population to drop, temporarily nearing extinction.

70,000-100,000 years ago
Modern humans began to leave Africa.

65,000-35,000 years ago
Humans reached the Australian continent, crossing the water in canoes.



Over the Bering bridge
During the Pleistocene Ice Age, a land bridge formed to connect Asia and North America. This allowed Homo sapiens to eventually migrate to North America.

The Neanderthal encounter
This migratory route, approaching Europe through Russia's grasslands, led to the discovery of the Neanderthals. Adopting a hunter-gatherer lifestyle, interbreeding between early modern humans and Neanderthals give many of us traces of this species in our DNA today.

Inherited Neanderthal genes include a prominent brow, larger nostrils and a receding chin

Island exploration
The people following this migration were some of the first to develop rice agriculture before heading out to sea to areas such as Indonesia.

Lucy became the world's most famous early human ancestor

"Different migration patterns saw the species split"

50,000 years ago
A group leaves the tropical areas of South Asia to explore inland.

20,000 years ago
Moving towards North Asia, groups tackled vast ice sheets on their route from East Asia to North America.

15,000 years ago
After crossing into North America, by 15,000 years ago humans had covered the entire land mass south of this icy region.

14,000 years ago
Within one thousand years of inhabiting North America, humans had migrated to the very tip of South America.

Victorian quack medicine

Find out about the 19th-century medication that caused more harm than good

Mercury for disease

Mercury pills were regularly prescribed for diseases such as typhoid, syphilis and parasites. While the metal may have helped some infections, it also resulted in many people experiencing toxic side effects. This created controversy as to whether it was the mercury or just the symptoms worsening.

Effectiveness ●●●○○
Toxicicity ●●●●●

© Getty

Radam's microbe killer

Claiming to cure tuberculosis, in 1887 William Radam used plant-based ingredients and water to create a substance that he passed off as a medicine that would kill all the microbes in your blood and cure you of most diseases. After the product was analysed in 1913, it was determined that each bottle was mainly water with almost undetectable levels of sulphuric acid.

Effectiveness ●○○○○
Toxicity ●○○○○

Source: Wiki

Laudanum painkillers

This combination of alcohol and opium resulted in an increased number of suicide cases as people overdosed on the remedy. As the concoction created euphoric sensations, these temporary highs stopped pain, but left many people addicted to the drug.

Effectiveness ●●●●○
Toxicity ●●●●○

© Getty

Leeches for sickness

Just the idea of having a leech suck your blood makes many of us feel nauseous. However, they were used in medicine for thousands of years as a form of bloodletting to relieve many illnesses, including nausea and morning sickness. Eventually the remedy was shown to weaken patients and cause infections, putting an end to the practice.

Effectiveness ●●○○○
Toxicity ●●○○○

© Getty

Carbolic acid germ killer

Joseph Lister invented this spray with the aim to rid infectious germs from the air. The acid steam could be used on people and entire rooms, aiming to create an antiseptic environment. Unfortunately Lister was unaware that inhaling the acid was incredibly dangerous and that germs carried on skin were more important to focus on.

Effectiveness ●●○○○
Toxicity ●●●●○

© Getty

Health is regarded as a top priority for most. When we go to the doctor's, we go with confidence that they will provide us with the correct medication based on the best medical findings.

While scientific research has brought medicine and treatment to the levels they are today, in times gone by anything and everything was experimented with as potential cures and remedies. People would trust anything from pharmacists or prescribed by their doctor that could make them feel better. But some of the most popular medicines of Victorian times simply didn't work, or worse, were dangerously addictive and had the potential to cause permanent damage to anyone who took it. In an era when legislation didn't exist to control false advertising, these medicines were often given sensational names like 'Dr Kilmer's Swamp-Root Kidney Cure' and 'Hamlin's Wizard Oil'. They were known as 'quack medicines'.

The term quackery comes from an old Dutch word, 'quacksalver', originally used to refer to someone who uses home remedies and false knowledge with the aim to cure. The exploitation of ignorance in selling quack medicine was rife during the 19th century.

Chloroform for hiccups

Today we might try holding our breath or drinking water backwards to combat a case of hiccups. If you lived in the 1800s, however, you could be advised to inhale chloroform, a chemical found in floor polish. By taking these lengths to reduce the annoyance of hiccups, vital organs paid the price. Chloroform has the potential to damage the nervous system as well as the liver and kidney.

Effectiveness ●●●○○
Toxicity ●●●●●

© Getty

Electric belt

Sending electricity through the wearers' body, electric belts held curing claims for most issues – from back problems and chronic nervous diseases to infertility or even a simple lack of confidence.

Effectiveness ●●○○○
Toxicity ●●○○○

© Wellcome Images

Strychnine for fatigue

For nearly two centuries people used strychnine pills to keep alert. Athletes took them to keep energy levels up, while students used the medication to stay awake during exams. The alkaloid could be used for almost anything. Unfortunately, just five milligrams of the stuff was enough to kill. Less than this amount caused rapid heart rates, loss of consciousness and cold sweats.

Effectiveness ●●●●○
Toxicity ●●●●●

© Getty

Anti-asthma cigarettes

In the 19th century, cigarettes were widely considered to benefit health. Asthmatics would inhale smoke in hope of ridding themselves of the condition, but today we know it kills and damages the bronchioles, only making this limited breathing worse.

Effectiveness ●○○○○
Toxicity ●●●●○

© Pixabay

Cocaine for toothache

Today's illegal drugs were prescribed for an extensive list of illnesses. In another case of creating drug addicts from patients, cocaine was used as an anaesthetic for toothache. Dentists also used cocaine during surgeries.

Effectiveness ●●●○○
Toxicity ●●●○○

© Getty

For some medical inventors, it wasn't even important how true their claims were – it was about creating a believable business model. The art was in the convincing. From drugs that could be sold to combat any pain, leaving patients on a medical high, to water-based potions that did nothing but make people feel like it was doing them good. Tapeworms were voluntarily ingested with the focus on weight loss, while mothers would innocently drug their crying babies with opioids, believing the after-effect of them passing out was a triumph for sleep. The medical world has evolved dramatically since, to the scrutinised levels we have arrived at in the modern world.

Hearing about some of this Victorian medical treatment, you may feel relieved that our ailments today can be treated in a more scrupulous fashion, by legitimate dotors and pharmacists. You might even be appalled that these dodgy treatments were allowed until 1860 (the Adulteration of Food and Drink Act) in the UK and 1906 in the US (Pure Food and Drug Act). However, we need to give the Victorians some credit, as the only way we've attained today's medical standards was to learn from some of these crazy experiments of the past.

© Illustration by Nicholas Forder

WIN!

A PAIR OF EARPHONES

This month we are giving away a pair of handcrafted MW07 True Wireless Earphones by Master & Dynamic

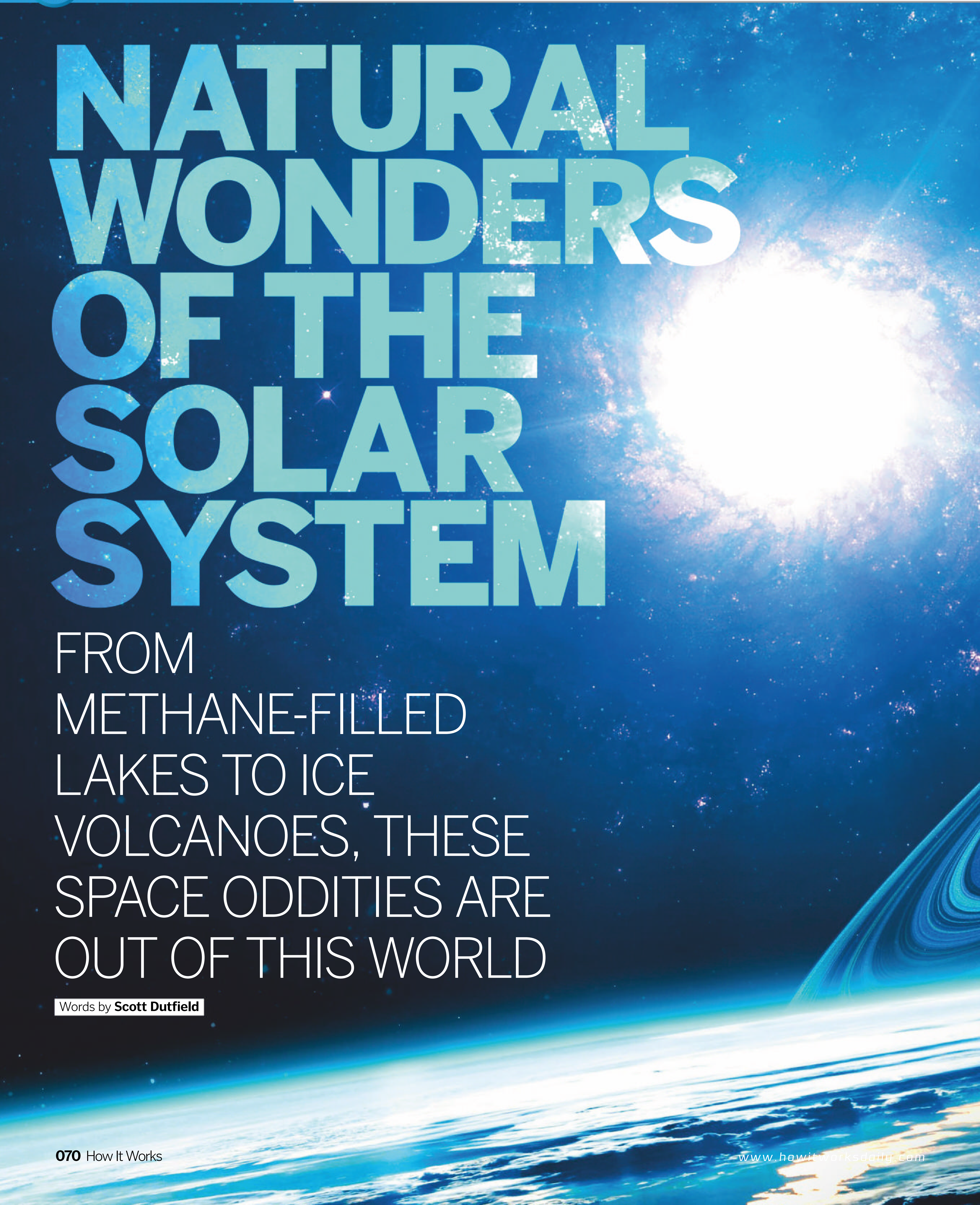
For your chance to win, answer the following question:

What is the largest planet in our Solar System?

a) **Mars** b) **Jupiter** c) **Uranus**

Enter online at **howitworksdaily.com** and one lucky winner will win!

Terms and Conditions: Competition closes at 00:00 GMT on 16 January 2020. By taking part in this competition you agree to be bound by these terms and conditions and the Competition Rules: **futuretcs.com**. Entries must be received by 00:00 GMT on 16/01/2020. Open to all UK residents aged 18 years or over. The winner will be drawn at random from all valid entries received, and shall be notified by email or telephone. The prize is non-transferable and non-refundable. There is no cash alternative.



NATURAL WONDERS OF THE SOLAR SYSTEM

FROM METHANE-FILLED LAKES TO ICE VOLCANOES, THESE SPACE ODDITIES ARE OUT OF THIS WORLD

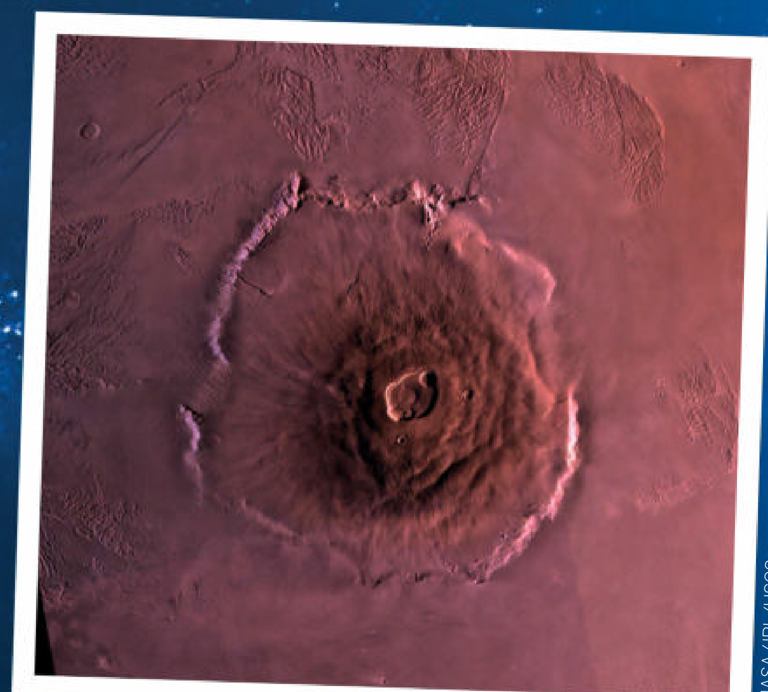
Words by **Scott Dutfield**

© Getty

GIANT MOUNTAIN

Named after the great Mount Olympus in Greece, Olympus Mons is the tallest peak in our Solar System. Towering skywards 25 kilometres from its base and spanning 624-kilometres wide, it dwarfs Earth's highest mountain, Everest, which is around 8.8-kilometres high. Known as a shield volcano, Olympus Mons formed over millions of years by slowly piping core lava over its banks to create a broad shield appearance. Shield volcanoes are not exclusive to Mars; many can be found right here on Earth, like Mauna Loa in Hawaii.

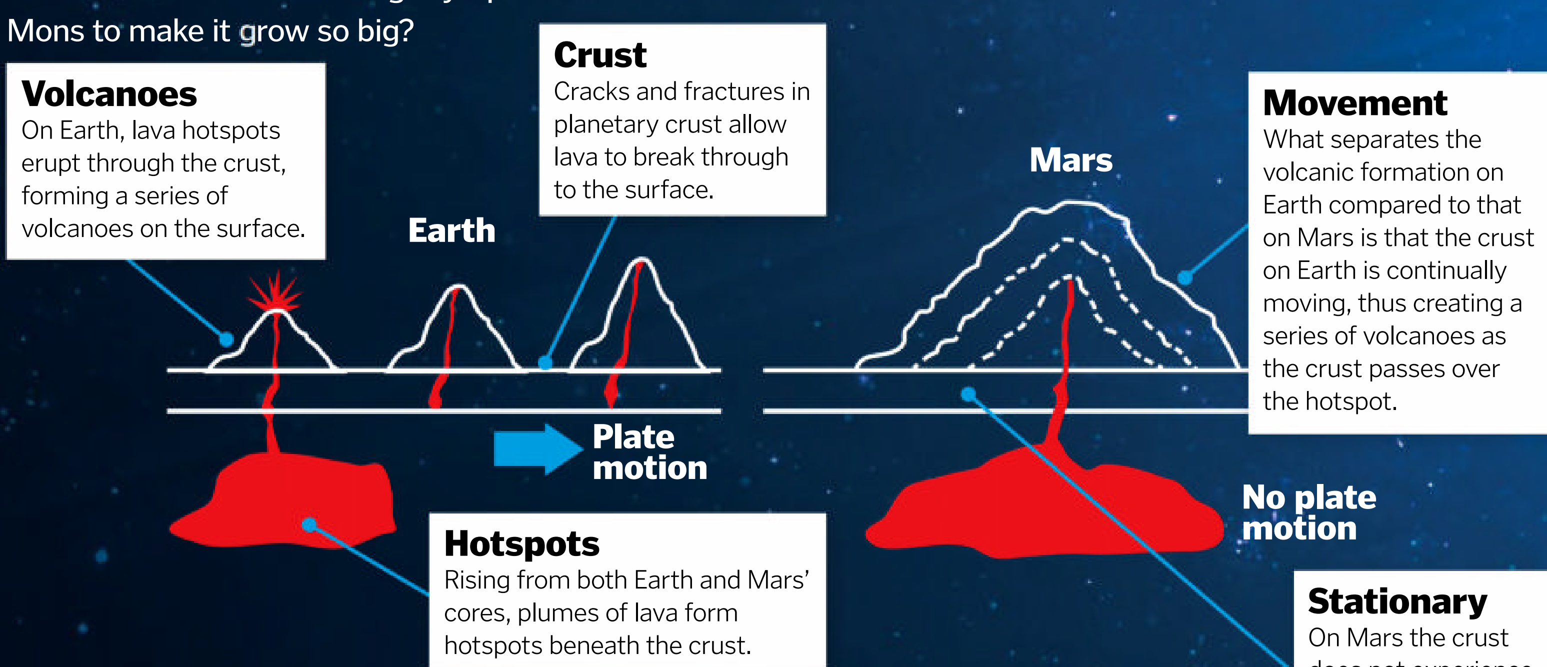
What separates Martian volcanoes from Earth's own is the way in which they form. Typically on Earth, a volcano will grow over a plume of molten lava below the crust and erupt onto the surface. However, this process can only occur as long as a volcano sits above the lava hotspot. Over millions of years the Earth's crust naturally shifts and moves around the planet at a snail's pace, around 0.6 to ten centimetres a year. This tectonic movement exposes new crust to the heat of plumes below, and a new volcano can form, almost like a volcanic conveyor belt. However, on Mars the planet's crust remains stationary, which means that any volcanoes sitting above a hotspot continually grow.



Olympus Mons formed over millions of years as lava continually flowed over its banks

Raising a giant

What has Mars been feeding Olympus Mons to make it grow so big?



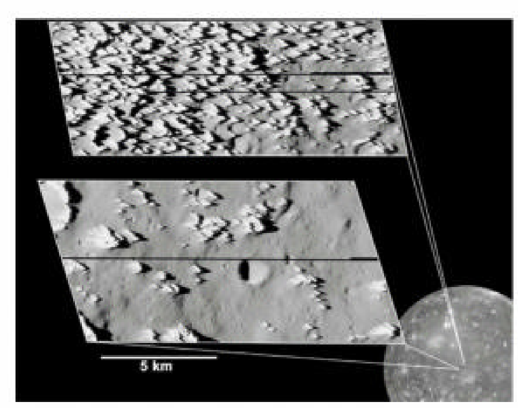
Putting Olympus Mons into perspective

Spires of icy 'knobs' have been found on one of Jupiter's massive moons

ICY SPIRES

Orbiting our largest planetary neighbour, Jupiter, Callisto is itself a giant in space, holding the record of third-largest moon in our Solar System with a circumference at its equator of 15,144 kilometres. What makes this moon a real space oddity is its cavernous appearance.

Coated in rock and ice, Callisto's surface is home to kilometres of icy spike-like 'knobs', reaching up to around 100 metres tall. Devoid of volcanoes and wind, these spires have not been created in the same way they might have been if they were on Earth. Instead these spires have risen from the ground as a result of continual bombardment from meteorites. On impact, dust and ice are thrown up into the air, and over time have settled into these planetary ice spikes. Due to the lack of natural erosion from wind and rain that we see on Earth, these spires will be around for a long time.



NASA's Galileo spacecraft snapped this shot of the spire from 138 kilometres above the surface back in 2001

Artist's impression of Titan's lake-covered surface

Due to its nitrogen-rich atmosphere, Titan's surface exhibits an organic brown hue

METHANE LAKES

Over 1.4 billion kilometres from Earth on one of Saturn's 53 confirmed moons, Titan, is a world that resembles Earth… with some substitutions. Rocky outcrops are replaced with icy mountains, and rather than raging rivers of water, lakes of methane have carved the surface. Much like our planet has a cycle of evaporation and precipitation to form rain, Titan also experiences cycles of rainfall, but it's very different to Earth.

Liquid methane is evaporated around the moon's equator and falls as rain at the polar regions. On Earth, hydrocarbons such as methane act as a gas until placed in a pressurised tank. However, due to Titan's extremely cold temperatures – dropping to around minus 179 degrees Celsius – hydrocarbons act like a liquid, which follows a similar cycle we see on Earth. Without a strong gravitational pull like the one we experience on Earth, methane raindrops fall in slow motion. Compared to the 9.2 metres per second that rain falls on Earth, on Titan raindrops descend at a speed of only 1.6 metres per second.

The first record of the Great Red Spot is a drawing from 1831 by amateur astronomer Samuel Heinrich Schwabe

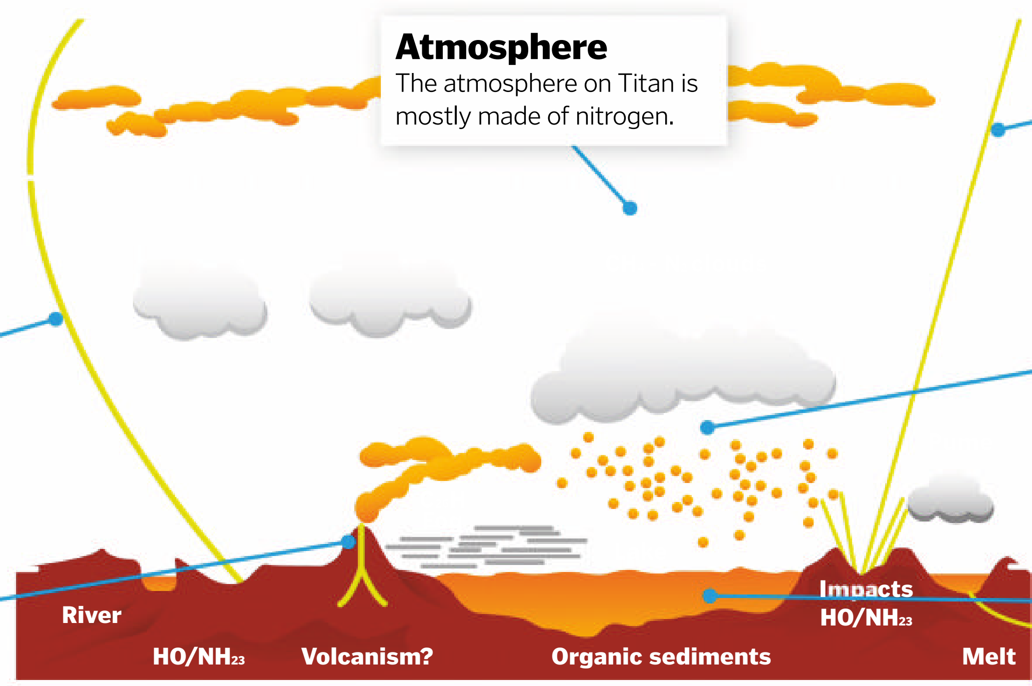
JUPITER'S RED EYE

One of Jupiter's most recognisable features is the enormous red spot marking the gas giant's surface. Large enough to engulf the Earth, this spot is in fact a swirling storm, spinning at speeds of at least 430 kilometres per hour. It's still unknown as to when the scarlet storm started, but records show that people have been observing Jupiter's Great Red Spot for around 400 years.

Image studies conducted on the spot between 1979 and 2016 have shown that the spot appears to be shrinking, becoming rounder and taller and intensifying in colour. It's still relatively unclear as to why Jupiter's storm is changing, although NASA's Juno spacecraft is currently orbiting the gas giant collecting data in the hopes of finding an explanation.

Methane showers

How liquid methane rains down from Titan's sky



Atmosphere
The atmosphere on Titan is mostly made of nitrogen.

Escaping Titan
Floating as cloud and haze, methane interacts with organic compounds in the atmosphere, releasing hydrogen out into space in the process.

Evaporation
Although Titan doesn't receive as much heat from the Sun as Earth does, it still receives enough to evaporate methane from its lakes.

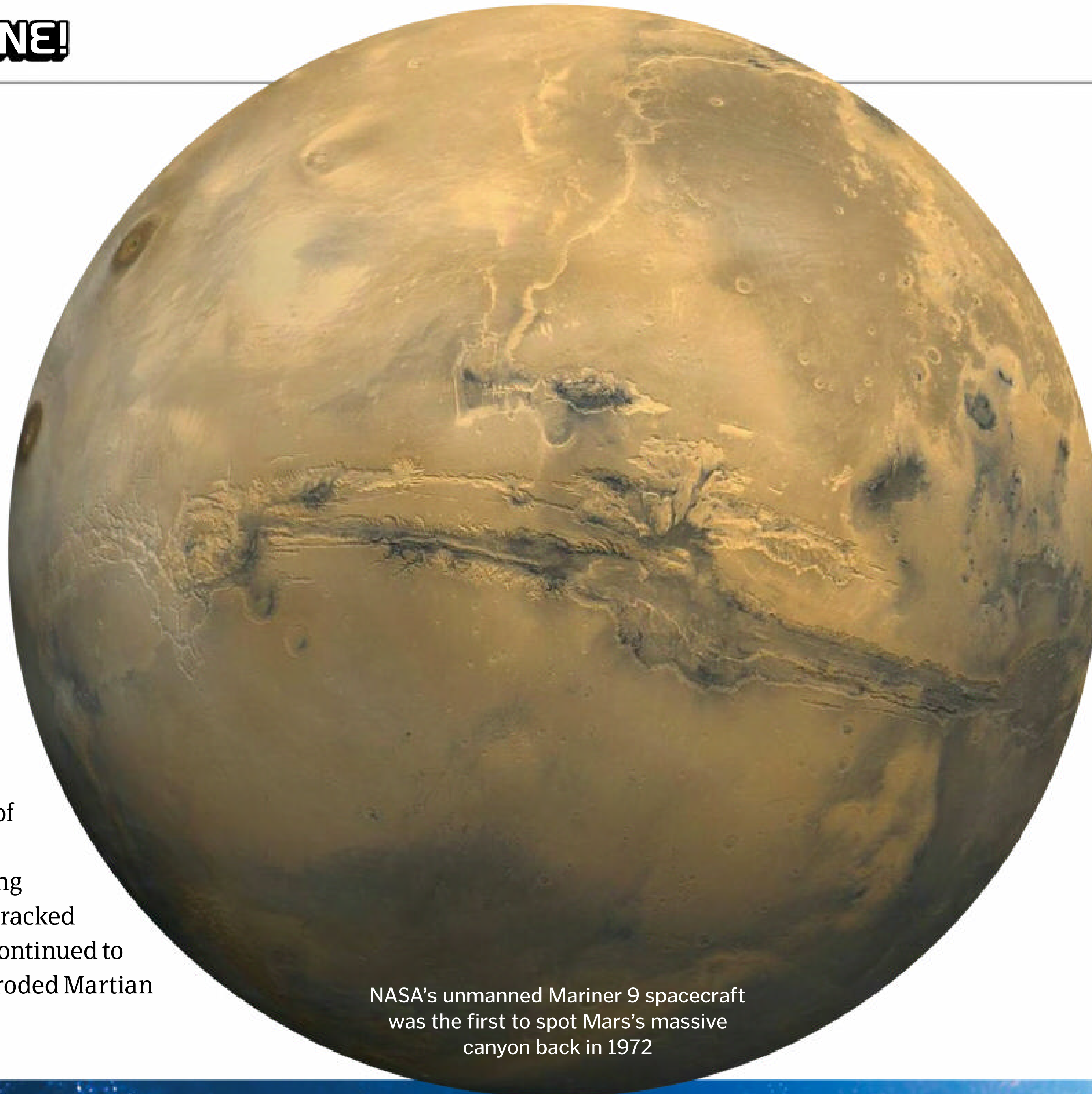
Condensation
Evaporated methane forms clouds in Titan's atmosphere until it reaches around minus 185 degrees Celsius and falls as rain.

Volcano
Methane stored in the crust is heated and sent into the atmosphere via volcanic activity.

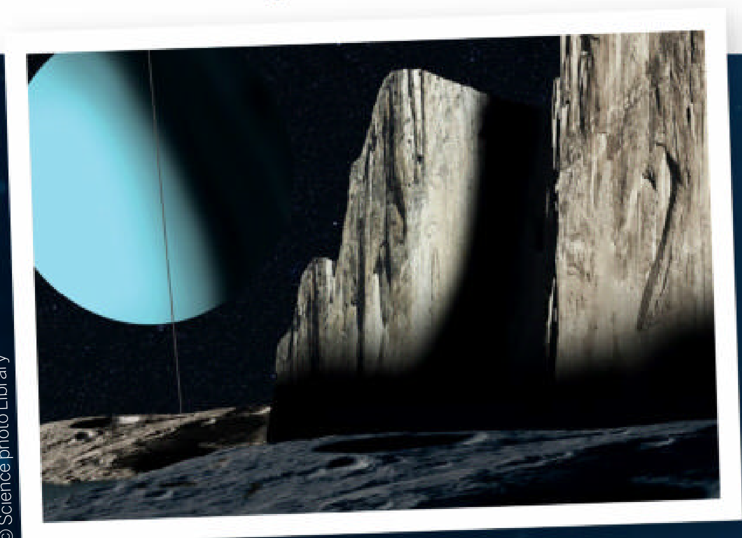
Methane lake
In the northern regions of Titan, seas and lakes are comprised of liquid methane.

THE EVEN GRANDER CANYON

Like a scar on the face of Mars, Valles Marineris cuts around eight kilometres into the planet's crust. This grand valley stretches 4,000 kilometres in length and 600 kilometres wide, making it the largest canyon in the Solar System. Valles Marineris is made up of a collection of troughs, much like Earth's own Grand Canyon in Arizona. It's still relatively unknown as to what caused this enormous blemish on Mars' surface, although there are plenty of theories. The leading idea relates to a particularly eruptive region of Mars called Tharsis. This region of the Red Planet is home to a series of giant volcanoes, including Tharsis Montes and Olympus Mons. It's believed that around 3.5 billion years ago, during their volcanic formation, Mars' crust was stretched and cracked to form fractures on the surface. Over time these cracks continued to grow and, alongside Mars' once-flowing surface water, eroded Martian rock to carve a canyon unrivalled in size.



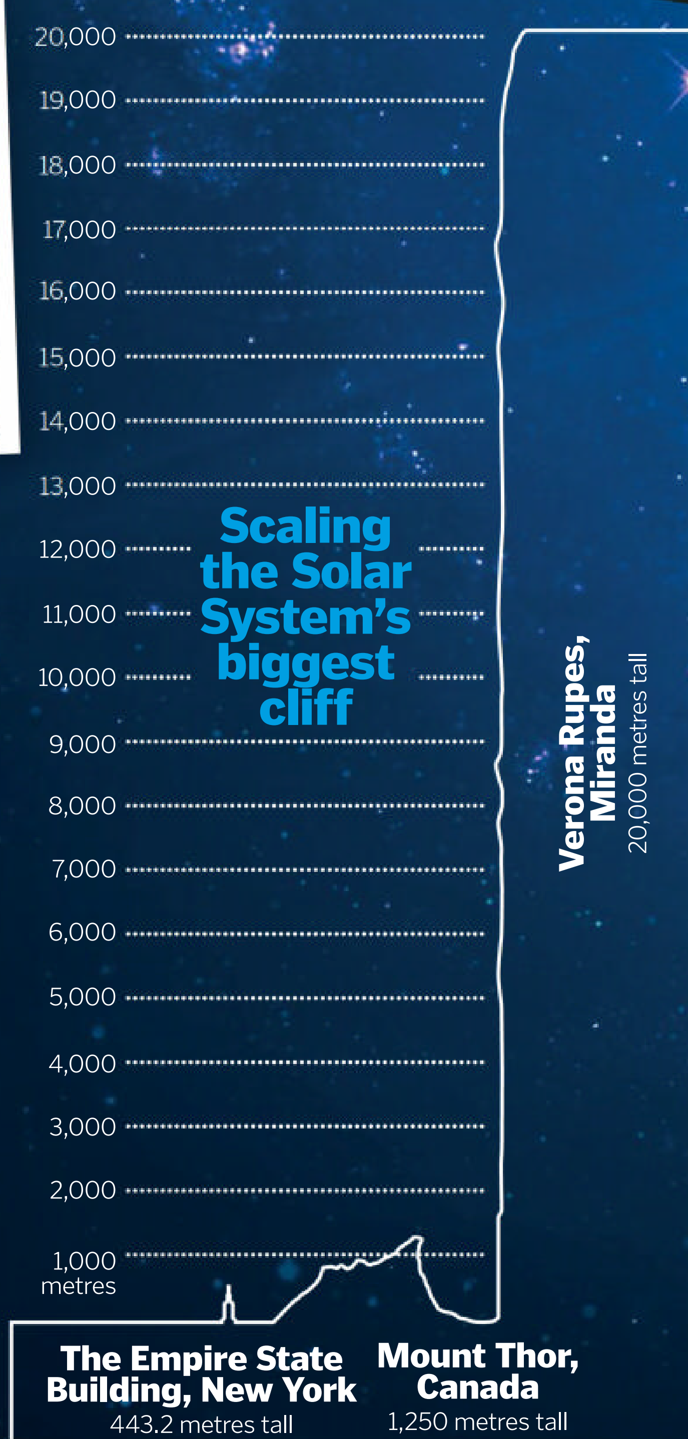
NASA's unmanned Mariner 9 spacecraft was the first to spot Mars's massive canyon back in 1972



TALLEST CLIFF

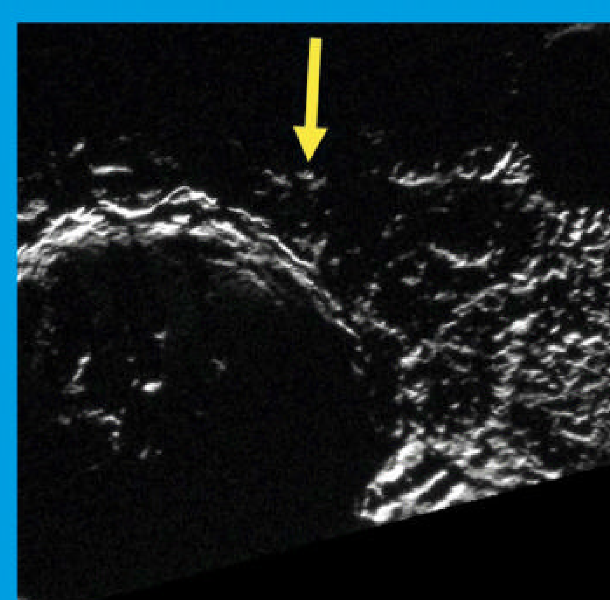
Circling Uranus, between 2.6 and 3.2 billion kilometres from Earth, the moon Miranda has a cliff so tall you would need to stack around 45 Empire State Buildings to reach to the top. Around 20-kilometres high – or deep, depending on where you're standing – Verona Rupes is the tallest cliff in our Solar System. This thrill-seeker's dream was first captured in 1986 by NASA's satellite probe, Voyager 2.

Due to the reduced gravity on Miranda, falling from the top it would take you around 12 minutes to reach the bottom, albeit at 200 kilometres per hour. Scientists are still unaware of how this cosmic cliff was created, but theories allude to the possibility of a major impact on the moon's surface.



ETERNAL SUNLIGHT

Imagine a place where the Sun rarely sets and mountains are eternally bathed in light. Well on Mercury, such a place exists. On its 88-day journey around the Sun, Mercury experiences virtually no tilt on its axis, meaning some areas on its surface are continually exposed or shadowed from the sunlight. During the daytime Mercury's surface can reach a scorching 430 degrees Celsius, and at night can fall to minus 180 degrees Celsius. The 'peak of eternal light', found on Mercury's south pole, is lit up by the Sun around 82 per cent of the time.



At Mercury's south pole, a 'peak of eternal light' has been discovered which rarely evades sunlight

FROZEN GEYSERS

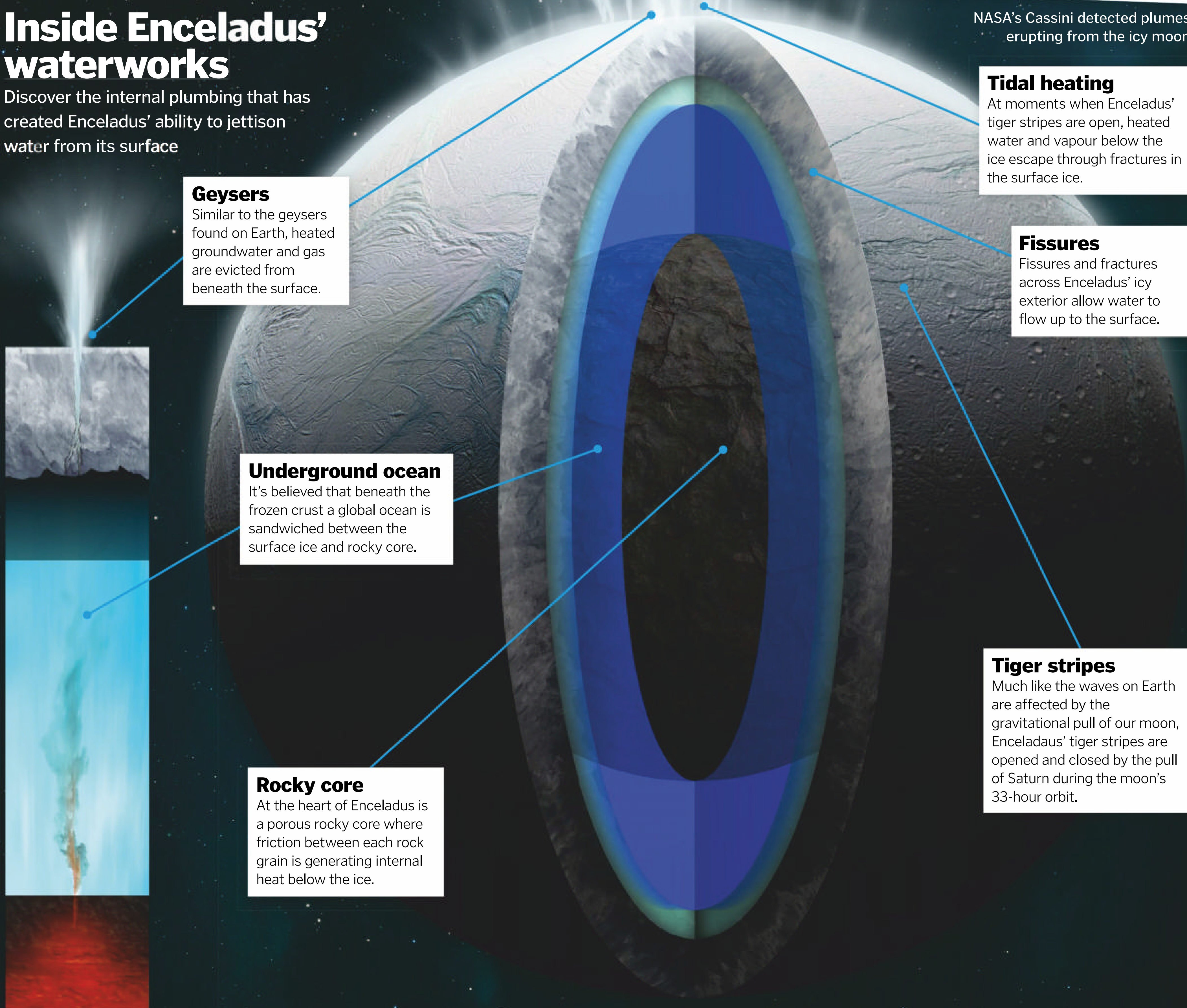
AR ZONE! SCAN HERE

Circling among the iconic rings of Saturn is a moon spitting water and ice out into space. Enceladus is Saturn's sixth-largest moon, spanning around 500 kilometres in diameter. What makes it different from its lunar cousins are four 135-kilometre fractures at its south pole which are home to around 100 geysers that spray water, ice and vapour at around 400 metres per second. Commonly known as Enceladus' 'tiger stripes', geyser activity at these cavernous stripes was discovered in 2005 when NASA's research spacecraft, Cassini, captured the first hints of this icy phenomenon. Since then scientists have uncovered that the source of these frozen fountains comes from a global ocean some ten kilometres beneath Enceladus' icy surface.

NASA's Cassini detected plumes erupting from the icy moon

Inside Enceladus' waterworks

Discover the internal plumbing that has created Enceladus' ability to jettison water from its surface



Geysers
Similar to the geysers found on Earth, heated groundwater and gas are evicted from beneath the surface.

Tidal heating
At moments when Enceladus' tiger stripes are open, heated water and vapour below the ice escape through fractures in the surface ice.

Fissures
Fissures and fractures across Enceladus' icy exterior allow water to flow up to the surface.

Underground ocean
It's believed that beneath the frozen crust a global ocean is sandwiched between the surface ice and rocky core.

Tiger stripes
Much like the waves on Earth are affected by the gravitational pull of our moon, Enceladaus' tiger stripes are opened and closed by the pull of Saturn during the moon's 33-hour orbit.

Rocky core
At the heart of Enceladus is a porous rocky core where friction between each rock grain is generating internal heat below the ice.

What will the world's biggest telescope see?

How the Square Kilometre Array project will probe the secrets of the universe

Words by **Jonathan O'Callaghan**

When you think of a telescope, you probably imagine some sort of tube with a large lens used to peer deep into the universe. But the Square Kilometre Array (SKA) is something entirely different. It will use antennae with a collecting area of about one square kilometre to probe radio waves from the universe like never before, and perhaps give us our best-ever glimpse into some of its earliest moments.

The SKA is being built primarily in two locations, one in Australia and the other in South Africa, along with several other smaller installations in other countries. The locations have been chosen as they are far from human infrastructure, meaning the antennae can observe the universe's radio waves around the clock without interference from terrestrial signals.

With contributions from 20 countries in total, headquartered at Jodrell Bank in the UK and set to begin operations in 2024, the SKA will be the largest radio telescope ever built. Together its thousands of antennae will be spread over an area of about a continent, making it 50 times more sensitive and 10,000 times faster at surveying the sky than any other telescope.

The project is expected to cost £1.3 billion and is being built in two phases, called SKA1-Low and SKA2-Mid. In 2027 the project will begin its full operation, using more than 100,000 antennae in total. Among its science goals, the SKA will probe Einstein's theory of general relativity, observe how galaxies evolve and even look for signals of advanced extraterrestrial life in other solar systems.

All told, this is one of the most ambitious astronomy projects attempted in the history of humanity – and in just a few years we might be reaping its vast science benefits.

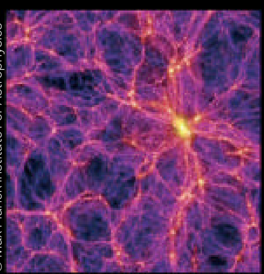
Thousands of radio dishes are spread out across several continents

© SPDO/TDP/DRAO/Swinburne Astronomy Productions

> "The antennae can observe the universe's radio waves around the clock"

Mission goals

What does the project hope to discover?



© Max Planck Institute For Astrophysics

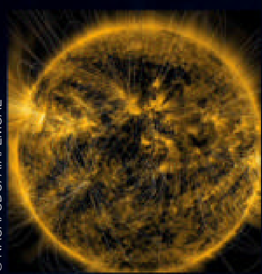
Structure of the universe

By observing the flow of hydrogen between galaxies, the SKA will examine the large-scale structure of the universe, thought to be dominated by dark energy.

© NASA/WMAP Science Team

The Dark Ages

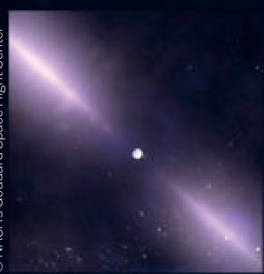
The SKA will look back to when the first stars and black holes formed in a period called the Dark Ages, a time when there was very little light left over in the universe after the Big Bang.



© NASA/SDO/AIA/LMSAL

Magnetic fields

The SKA will study the role that magnetic fields play in the formation and evolution of stars and galaxies by observing the radio waves emitted by electrons in these fields.



© NASA's Goddard Space Flight Center

General relativity

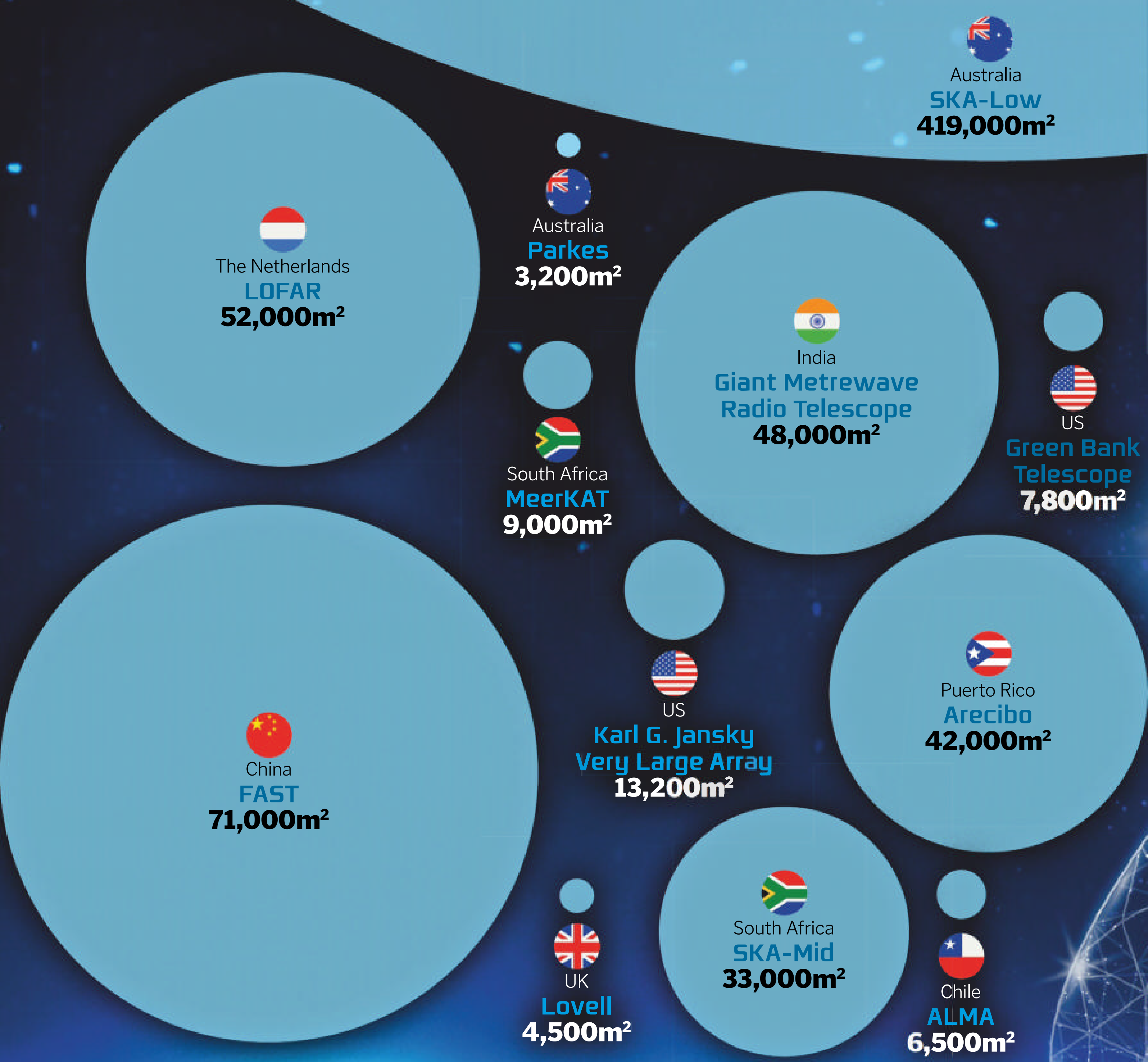
Rapidly spinning stars called pulsars detected by the SKA will allow scientists to probe Einstein's theories of gravity. Pulsars can also help hunt for gravitational waves in the early universe.

© ESA/Hubble M Kornmesser

Search for life

With its vast radio power, the SKA will look for any radio signals being emitted from other planets. If found, these could be an indicator of advanced alien life somewhere in the universe.

LARGE RADIO TELESCOPES ACROSS EARTH



Radio astronomy in action

To observe the universe, radio telescopes can make use of a technique called interferometry, which involves combining observations from multiple antennae to create a single image. Radio waves, while invisible to the human eye, come from a variety of objects in the universe and can be converted into an image that we are able to comprehend.

The larger the area your antennae are spread over, known as your 'collecting area', the higher your resolution. It's similar to having a bigger mirror on an optical telescope, but here the mirror is the antennae. And the SKA will make use of the largest 'mirror' ever devised – about a million square metres in total – with a dense cluster of antennae at its central regions spreading out into thinner 'arms'. This will allow it to detect radio signals from a variety of sources, from magnetic fields on the Sun to distant hydrogen.

5 tonnes
As the largest Ajax module, Apollo's crane alone weighs the equivalent of 11 horses.

3
Crew members include a driver, commander and gunner.

1500m
Its cannon can hit a target from a distance greater than the length of 14 football pitches.

© General Dynamics

© Richard Watt/MOD

42 tonnes
Ajax's maximum weight is around 20 times that of your average car.

71 kph
Ajax can travel three times faster than a running bull.

DIGITAL DEFENDERS

21ST-CENTURY ARMOURED VEHICLES

Meet the Ajax, a new family of smart army vehicles for modern battlefields

Words by **Ailsa Harvey**

Soldiers have to be quick thinkers, processing data and analysing situations as they play out before coming to an informed and tactical decision. Distributed across a fleet of separate armoured vehicles, crucial information needs to be shared as effectively as possible. Now there is a new family of vehicles aiming to make these processes easier and more efficient during missions: the Ajax family.

Described as the eyes and ears of the British Army, the Ajax armoured fighting vehicles (AFVs) are the first to be fully digitalised. Showing confidence in their performance, the new vehicles have been ordered as a replacement to the CVR(T) (Combat Vehicle Reconnaissance (Tracked)). While its armour is much heavier, Ajax can maintain similar speeds to the CVR(T) fleet, giving them a greater power-to-weight ratio. Corporal Clunn, who is working on the Ajax programme, describes the experience of driving Ajax as "like no other".

"You place a demand on the steering and it follows your direction," Clunn says. "You hit the breaks and the full weight of the vehicle comes to a stop. It feels like you are indestructible."

Perhaps the most groundbreaking feature, however, is its digital technology, bringing army vehicles into the 21st century with the all-weather intelligence and surveillance systems. Integrated with Electronic Architecture, they can detect threats visually and acoustically, instantly responding and acting on these findings far quicker than a human could process. Ajax's digital software is then able to communicate critical data to other vehicles, making army missions smoother and more efficient. Digital maps can be edited within Ajax vehicles and shared across a whole battlegroup in a matter of seconds.

The six Ajax variants are being produced by UK company General Dynamics, who are based in South Wales. While each of the Ajax variants differs slightly in components and primary roles, they all share the core properties and allow all operations to take place from within the armour.

In the future the innovative new software has the ability to continuously improve as digital technology advances – even once the vehicles are built. Working in a similar fashion to a smartphone app update, the platform's internal data can be updated and widely distributed.

© General Dynamics

Inside General Dynamic's warehouse, where the tanks are put together

Q&A

Staff Sergeant Gavin Smith of the Royal Lancers

© MOD

What does it feel like to be in control of Ajax?
To operate an Ajax from a commander's perspective is like stepping into the future. Crew comfort is better than it has ever been in an armoured fighting vehicle. It gives crews the ability and confidence to operate in all environments and will lead the way on the modern battlefield.

What is the most beneficial feature of Ajax?
The platform's survivability suite – comprising of a collective protection system – is the biggest game changer for me. It enables the crew to operate under armour in all environments, such as a chemical or biological weapon environment. Another part of the survivability system that will give us the edge is the laser warning system, as it gives the platform the ability to detect incoming laser threats from all directions.

How does the digital vehicle compare with others you have used?
Ajax is a complete game changer for the user with its advanced levels of mobility, lethality, survivability, communications and intelligence through its revolutionary Electronic Architecture. The high levels of reliability will allow the platform to operate for longer periods without Combat Service Support (CSS), which legacy platforms can't match. Every platform will allow video, picture and audio to be transmitted from it, too, which is a real battlefield asset.

How will digital platforms improve future army performance?
The modern army is working towards a fully integrated battlespace management system, enabling communications between land, sea and air – Ajax achieves this. The combined awareness systems will give the fighting crew and driver the ability to observe, listen, engage and navigate from within the vehicle while maintaining awareness of their surroundings. Ajax is the future, and with its potential for growth, it should remain at the cutting edge.

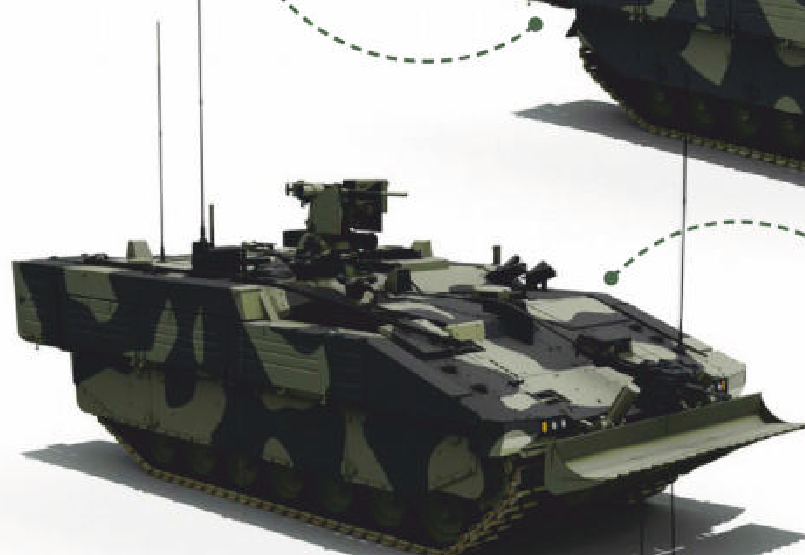
The Ajax family

Using a modular system with Ajax at the core, elements can be added to create new variants with specific roles

Ajax
This is the main model at the core of each version. The medium-weight vehicle provides each variant with all-weather intelligence and survivability.

Ares THE TRANSPORTER
Ares is built for reconnaissance purposes: to carry specialist troops safely across battlefields.

Apollo THE REPAIRER
Equipped with a crane system that's put into practise for towing damaged army vehicles, Apollo is also able to repair vehicles, including itself.



Atlas THE CARRIER
Like Apollo, Atlas includes a recovery package to recover casualty vehicles. This model includes an earth anchor and a pair of winches.

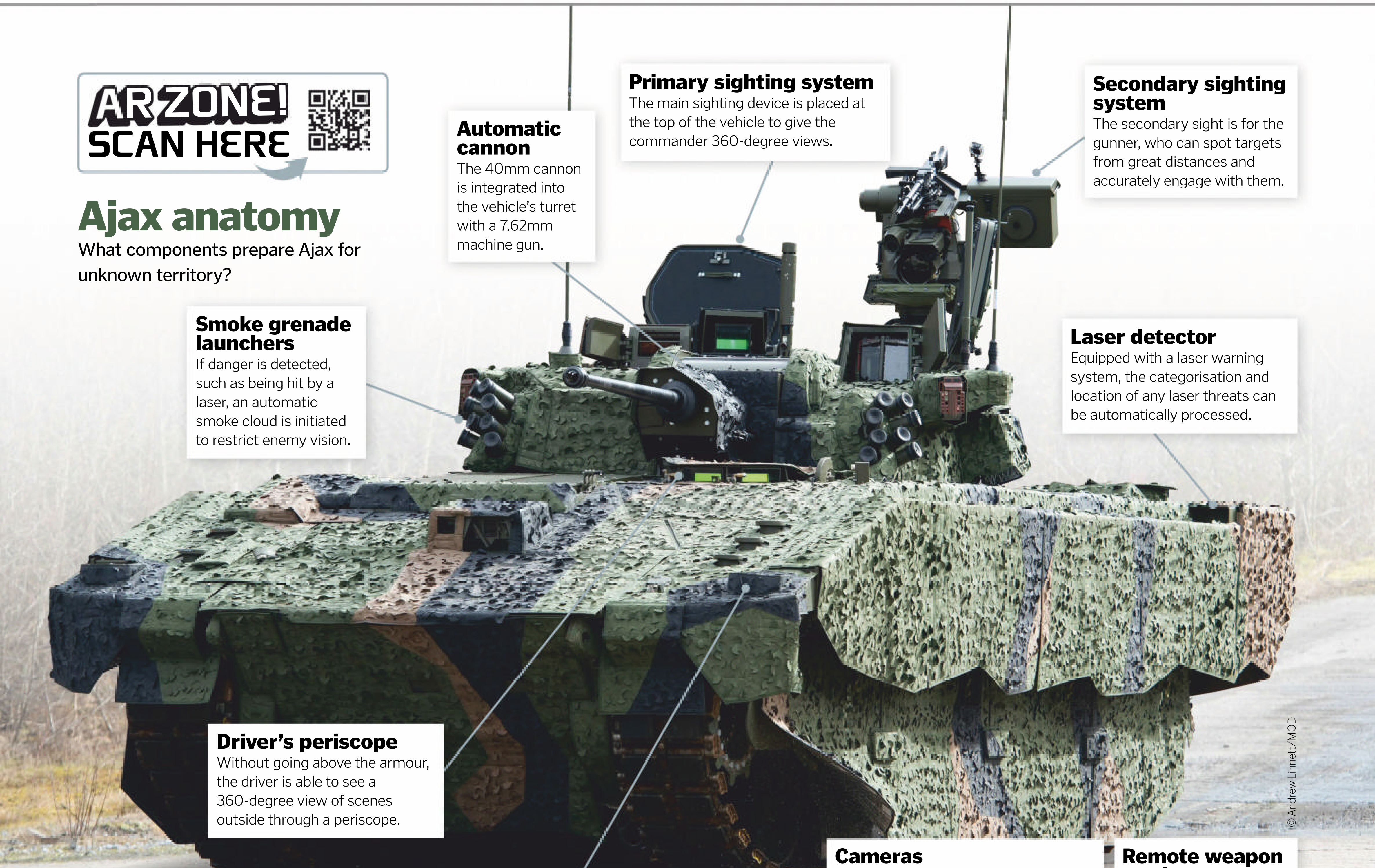
Argus THE LAND-ANALYSER
Assessing the battlefield environment, Argus provides accurate and real-time engineering data, streamed to commanders. This covers both natural and man-made structures.

Athena THE COMMUNICATOR
Essentially serving as mobile battlefield headquarters, Athena creates a protected area to process and manage information from all vehicles. Acting as an information provider, it enables better-informed decisions to be made during missions.

AR ZONE! SCAN HERE

Ajax anatomy

What components prepare Ajax for unknown territory?



Automatic cannon
The 40mm cannon is integrated into the vehicle's turret with a 7.62mm machine gun.

Primary sighting system
The main sighting device is placed at the top of the vehicle to give the commander 360-degree views.

Secondary sighting system
The secondary sight is for the gunner, who can spot targets from great distances and accurately engage with them.

Smoke grenade launchers
If danger is detected, such as being hit by a laser, an automatic smoke cloud is initiated to restrict enemy vision.

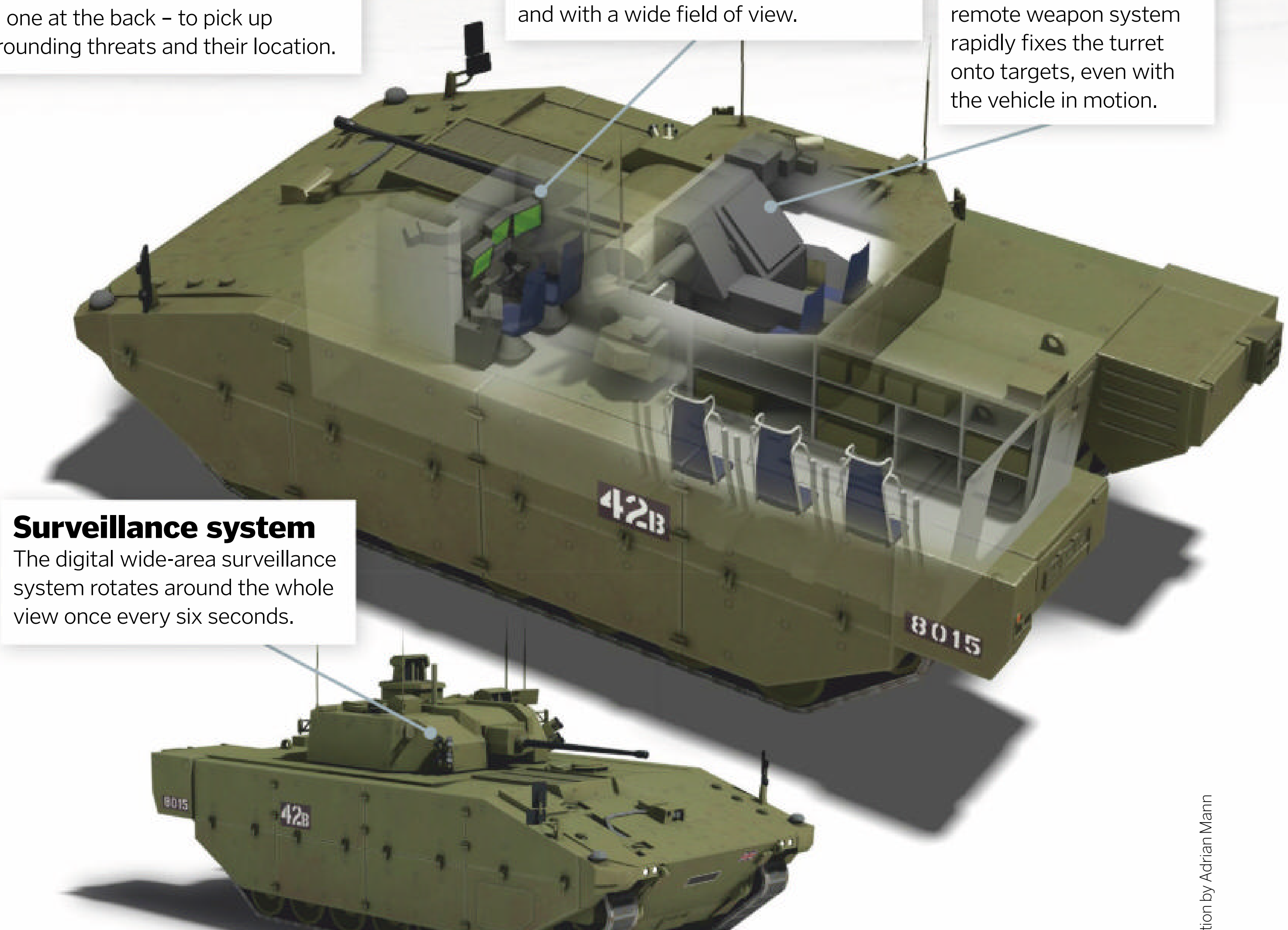
Laser detector
Equipped with a laser warning system, the categorisation and location of any laser threats can be automatically processed.

Driver's periscope
Without going above the armour, the driver is able to see a 360-degree view of scenes outside through a periscope.

Acoustic detectors
Ajax has three 'ears' – two at the front and one at the back – to pick up surrounding threats and their location.

Cameras
There are three cameras for the crew to look at, and eight around the vehicle, all suitable for day and night conditions and with a wide field of view.

Remote weapon station
Working with the stabilisation systems, the remote weapon system rapidly fixes the turret onto targets, even with the vehicle in motion.



Surveillance system
The digital wide-area surveillance system rotates around the whole view once every six seconds.

Pre-field preparation

Before putting AFVs to use, they need to go through rigorous testing to ensure they can tackle difficult terrain, weapon exposure and harsh conditions without degradation. Ajax vehicles were put through trials in Sweden, during which they were subjected to temperatures of -40 degrees and the firing of over 3,500 cannons to test weapon capability.

There is no use having vehicles fit for all circumstances if those driving it aren't completely confident in manoeuvring it. To prepare soldiers, most of the training is done using simulation. This allows the vehicles to be preserved for the battlefield and means that the majority can be put to practical use rather than kept in training grounds. The heavy simulation includes all the digital aspects of the vehicle and even provides realistic sensations of the forces experienced. Around 80 per cent of the training is carried out on these simulators.

Using the simulators, drivers are able to connect to other vehicle devices to practice operating and communicating together as a troop of up to four vehicles.

BRAIN DUMP

Because enquiring minds need to know...

MEET THE EXPERTS

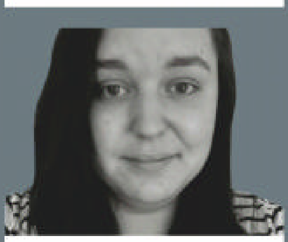
Who's answering your questions this month?

JO ELPHICK

MARK SMITH

ANDY EXTANCE

ANDREW MAY



AMY GRISDALE

Want answers?

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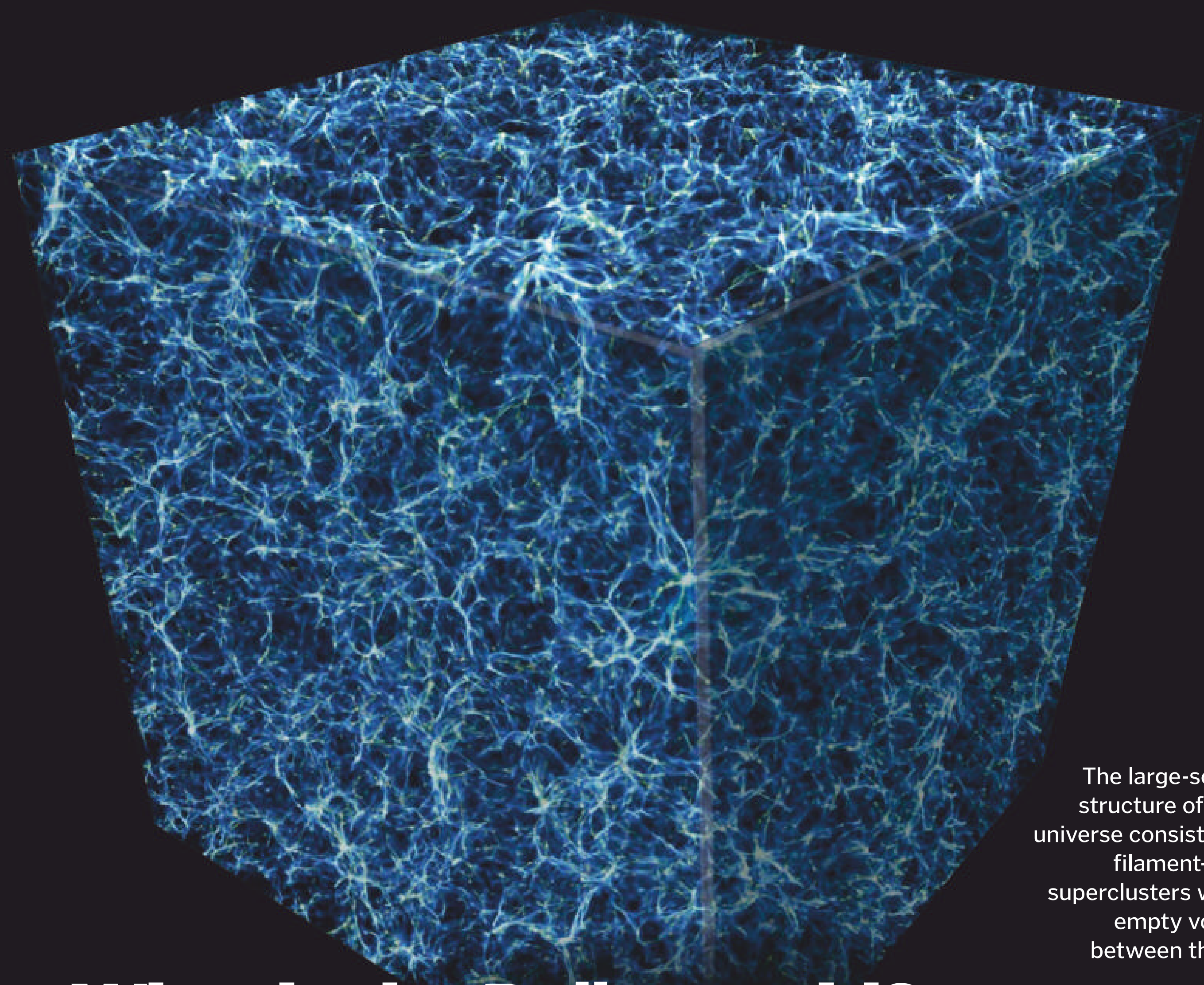
What are 'the bends'?

Howard Salazar

Not nice, that's for sure! Although it's the oxygen in the air we need to live, air is mostly nitrogen. Normally nitrogen dissolves in our blood. When scuba divers come back to the water's surface too fast, dissolved nitrogen can form bubbles. These bubbles block blood vessels, causing decompression sickness. One symptom, painful muscle spasms, is known as 'the bends'. The blocked blood vessels also make it hard to breathe, which is known as 'the chokes'. **AE**

Coming up too fast can cause nitrogen bubbles in divers' blood, leading to 'the bends'



The large-scale structure of the universe consists of filament-like superclusters with empty voids between them

© NASA

What is the Boötes void?

Patrick Butler

■ Just as stars clump into galaxies and galaxies into clusters, so clusters of galaxies congregate into even larger superclusters, hundreds of millions of light years across. Between these superclusters are equally enormous voids, containing almost no matter at all. One of the largest of these cosmic voids, 360 million light years in size, is half a billion light years away in the constellation Boötes. From its centre, the sky would look black in all directions. **AM**

An early sliding-box camera and accompanying equipment from 1853

© Getty

Why did early cameras take so long to take photographs?

Scott Michaels

■ The first photograph took eight hours to develop due to the slow shutter speed required to allow the copper plate, coated in bitumen, enough time in the light before an image could be captured. As the chemicals slowly reacted to the light, an image was etched in the surface. By 1939, the Daguerreotype camera used iodine-coated silver-plated copper which reacted far quicker to the surrounding light source and therefore sped the process up. **JE**

What in a snake's venom makes it poisonous?

Oscar Schulz

■ There are three main types of toxic secretion in snakes designed to stop prey in its tracks. Cytotoxins are rich in enzymes and kick-start digestion of soft tissue before the prey has actually died. Neurotoxins block chemical signals in the victim's central nervous system. These venoms can paralyse muscles and interrupt respiration. Haemotoxins affect the blood. Some stop blood from clotting, which can lead to massive internal bleeding. Other haemotoxins kill by thickening blood to the point where it can't circulate. **AG**

© Getty

Rough-scaled snake venom breaks down flesh, paralyses prey and interferes with blood flow all at once

Can humans safely eat cat or dog food?

Julia Morrison

■ Pet food makers claim people can. Humans test its taste, and supposedly can't distinguish dog food from paté, but we need different nutrients to our pets so we can't live off it. **AE**

© Getty

© Alamy

The Lycurgus Cup turns from green to red when light shines through it

What is used to colour stained-glass windows?

Nicholas Foster

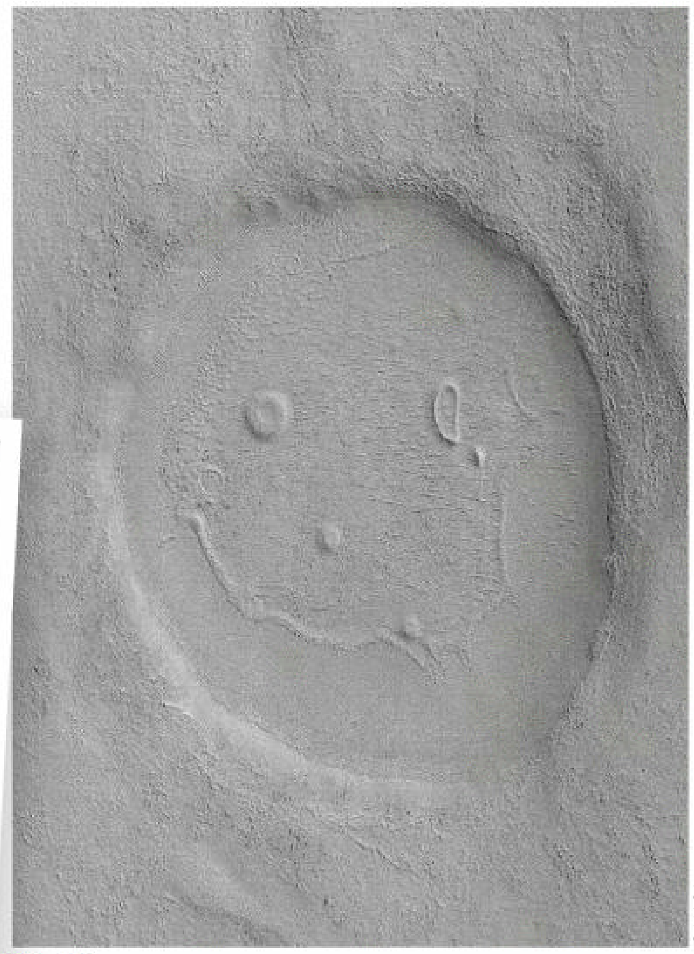
■ Metal salts and tiny metal particles have coloured stained glass for thousands of years. For metal particles, this uses the electron movement that makes metals useful as wires. Electrons at metal surfaces trap some colours of light and reflect others. Most large metal sheets reflect all visible colours, so the shiny surfaces work as mirrors. Smaller metal particles trap and reflect visible colours. As well as beautiful stained glass, this causes strange effects. The Lycurgus Cup, a green glass goblet from 4th-century Rome held in the British Museum in London, looks red when a light is put inside it. **AE**

How old is the youngest fossil?

Louise Keys

■ A preserved organism must be at least 10,000 years old before it can be considered a fossil. Anything younger than that will not be accepted by most palaeontologists. **JE**

© Getty



© NASA

The Mars Reconnaissance Orbiter snapped this happy-faced crater on Mars

Has NASA ever done an April Fools joke?

Niamh Patel

■ The NASA website has perpetrated a few April Fools – for example that the Moon is made of cheese, or that Mars is prone to humour because of its low gravity. **AM**

© Getty

How do double rainbows occur?

Graham Blythe

■ Sunlight bends when it shines through raindrops. It splits up into colours and creates a rainbow. If light is reflected by a droplet twice a faint mirror image appears over the original rainbow – its colours are inverted. **AG**

Is there a perfect white?

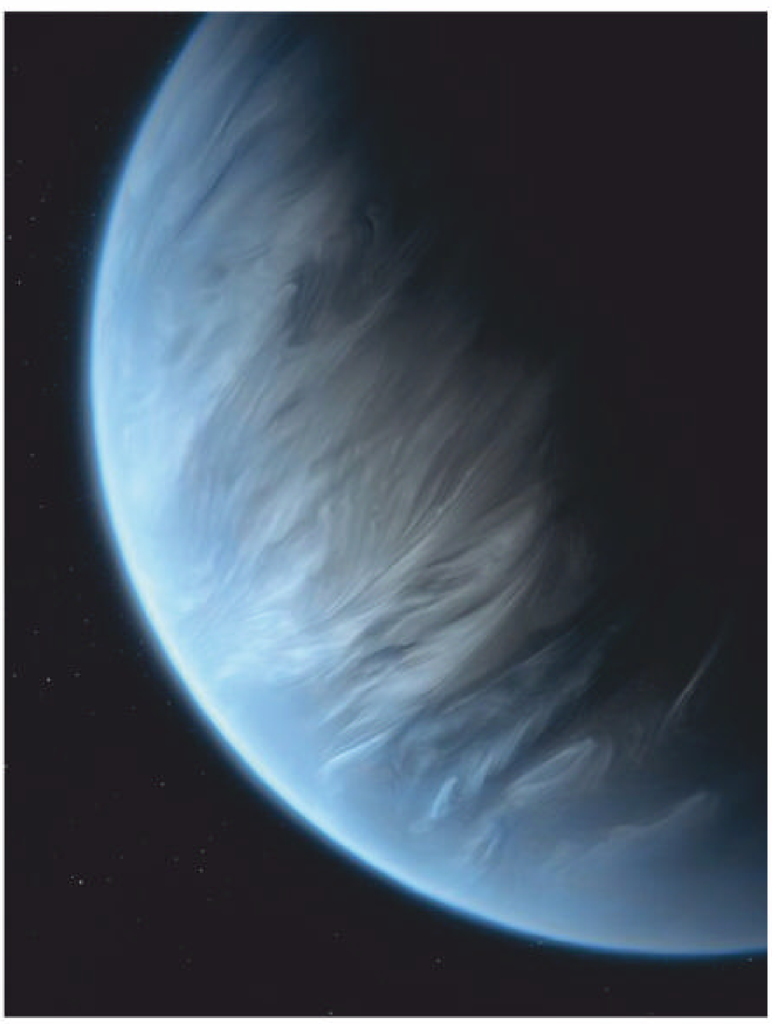
Lee Wong

■ We see white when many light colours reach our eyes at once. 'Perfect white' would mix all colours. The Sun doesn't produce completely perfect white, as some elements it contains absorb a little bit of colour. It would be very difficult, but it's theoretically possible to make perfect-white artificial light. **AE**

Which exoplanet is most likely to have life on it?

Ryan Davis

■ New exoplanets are being discovered all the time, so the answer to this question never stays the same for very long. The Habitable Exoplanets Catalog currently lists 55 promising candidates, sorted by Earth Similarity Index (ESI) – an indicator of how hospitable the surface temperature and other conditions would be for Earth-type life. Topping the list with an ESI of 93 per cent is Teegarden b, which orbits a red dwarf star just 12 light years from Earth. Another recently discovered contender for the title is K2-18b – the first Earth-like exoplanet known to have water vapour in its atmosphere. **AM**



Artist's impression of K2-18b, which appears hospitable to life due to the presence of water

Why are doorways so tiny in very old buildings?

Madonna Power

■ There are several reasons for tiny doorways in old buildings. People were slightly smaller during the 15th to 16th century and therefore didn't need high door frames, although the fashion did require them to be wide. Many doors may look small, but this is due to the rising street levels. As new roads were built on top of old tracks, the doors literally sank into the ground. Large manor houses often incorporated small doorways as a form of protection, since any intruder would be required to bend down in order to get in, thereby allowing the homeowner to attack first. **JE**

The front door of a Tudor timber-framed house appears much smaller than that of a modern home

© Stephan Sorkin

Is a virtual-reality experience with touch possible?

Kevin Wallace

It's already happening. Creating touch sensations is called 'haptics', and a lot of companies are already developing it. French firm Go Touch VR have created VRtouch, which straps onto your fingertips and applies varying pressure that matches what you'd be feeling in the virtual world. **MS**

© Getty

An electric car being charged. They may not burn fossil fuels, but electricity plants often do

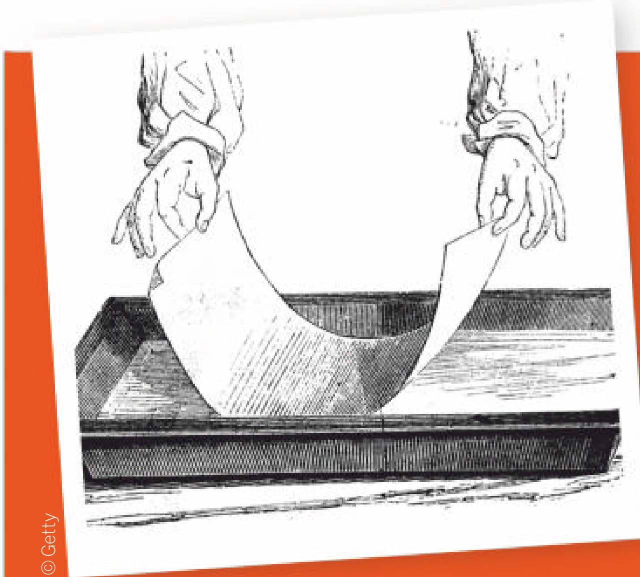
Are electric vehicles more environmentally friendly?

Joe Wells

All-electric vehicles are often held up as a greener alternative to petrol and diesel vehicles because they don't use fossil fuels in their engines.

It's not quite that simple though, because electric vehicles still have to be charged, and a lot of electricity is still produced using fossil fuels. In fact, 60 per cent of electricity around the world is produced using fossil fuels such as coal and gas.

It differs from country to country, however, and in Europe especially, things are different. In Belgium, for example, electricity is mainly generated using zero-emission energy sources, such as solar and wind power. **MS**



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Why was film originally shot in black and white?

Mohammed Abdalla

Black-and-white film was easier to work with and could be processed by hand in a basic darkroom with red lighting. Processing colour film was far more complex, requiring total darkness and automated technology which was extremely expensive. It also highlighted unrealistic scenery often used on early movie sets. **JE**

© Isorepublic Creative Commons

How can our phones take good pictures with a tiny lens?

Mike Earley

Smaller lenses mean less light can be taken in. That's compensated for with image-signal processors, camera control and post-processing software. Increasingly they also have more than one lens. **MS**

Arctic terns can travel 20,000 kilometres in just six months. That's halfway around the world

© Getty

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Why do some birds migrate to other countries?

Becky Lee

Around 40 per cent of birds are regular migrants. It's a survival tactic. Cold weather in Europe causes insect and rodent populations to plummet, so it's smart to seek out a warm climate crawling with prey. A few northern species visit the UK in winter because the weather is fairly mild compared to their Arctic origins. Sometimes huge flocks of birds fly to a new destination for a temporary feeding frenzy when their food source at home runs low. A few species flee to remote spots with few predators before moulting their worn-out flight feathers. They return home once they are able to fly again. **AG**

Why can I sometimes see the Moon during the day?

Paige Morgan

The Moon is illuminated by the Sun. To see a full Moon, the Sun must be immediately behind us, which only happens at night. But when the Moon is a partially illuminated crescent, the Sun can be in the sky at the same time. **AM**

© Getty

What is GPS and how is it free?

Teresa Warren

The Global Positioning System uses a network of satellites that beam radio signals to Earth. These signals contain super accurate time information. Your receiver, such as your smartphone, can figure out how far you've moved in relation to these satellites by comparing the time of the new signal to the one you received previously.

Because the system was developed by the US Air Force, it is paid for by American taxpayers, but free for everyone else. **MS**

A network of satellites enables us to find our location anywhere on Earth using GPS

© United States Government

BOOK REVIEWS

The latest releases for curious minds

> "Fan goes on to explain the biggest AI challenges we'll face in the future"

Will AI Replace Us?

A closer look at whether robots will ever rule the world

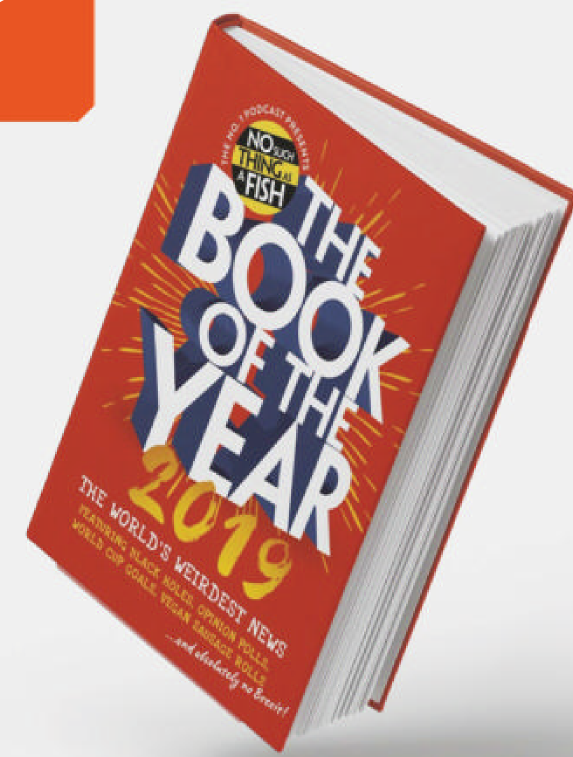
■ Author: **Shelly Fan** ■ Publisher: **Thames & Hudson**
■ Price: **£12.95 / $18.95** ■ Release: **Out now**

It's a big question, and one that technology enthusiasts have asked themselves since the first autonomous machines emerged in the 1950s. Will achieving true artificial intelligence be the final act of the human race? Listen to the Hollywood blockbuster and you'd be forgiven for thinking we're already doomed – according to them, we're already living in an artificial world created by our mechanical overlords while they farm us for energy. But do we really need to worry about computers taking over?

This book, part of the Big Idea series, starts by explaining the AI we already use, almost unknowingly, in our daily lives. It gives some simple, relatable examples – Netflix's recommendation algorithm, Apple's Siri assistant and the system that suggests things you might want to buy next from Amazon.

But these, author Shelly Fan explains, aren't the true AI that early pioneers imagined. Instead of being autonomous beings that learn complex ideas and form their own thoughts, these systems simply use machine learning to provide you with a service. They use simple data inputs to provide simple data outputs. But a more advanced form is still in development – one that can learn from its experiences and solve all kinds of problems. Fan goes on to explain the biggest AI challenges we'll face in the future – ethical questions, powerful enough computers and programming to avoid endangering us.

These are big concepts, but they're explained brilliantly in a format that's easy to digest and full of useful information. Like other books in the Big Idea series, every page has at least one image, along with a caption, to provide background knowledge on the subject. Potentially unknown terms, such as acronyms or technical names, are pulled out and explained in small notes around the text. And the text itself isn't written as one block; instead, it's split into different sizes, with the 'big ideas' being in the largest text. The idea is that if you only have 30 minutes, you can read the largest two font sizes to get an overview of the subject, but ideally you'd sit for a couple of hours to get more detail from the smaller text. It's a simple system that works really well, and makes this incredibly interesting and comprehensive book even easier to recommend. ★★★★★



The Book of the Year 2019

The alternative book of world records

■ Author: **No Such Thing As A Fish**
■ Publisher: **Hutchinson**
■ Price: **£12.99 / $24.95**
■ Release: **Out now**

Listeners of the hit podcast *No Such Thing As A Fish* will have an idea of what to expect here, and happily they are correct: page after page of intriguing and downright implausible facts about the year that was 2019 from the writing team behind hit panel show QI.

Proceeding in alphabetical order from The AA to Zuckerberg, Mark (okay, that's probably not the best example of its contents, but what can you do), there are items that might elicit moments of déjà vu – although thankfully Brexit is banned from the book – but others slide gloriously under the radar. We're thinking the Florida man who confused a swimming pool worker for an iguana and shot him, though not fatally, and the proposed South Korean robot museum to be built by robots.

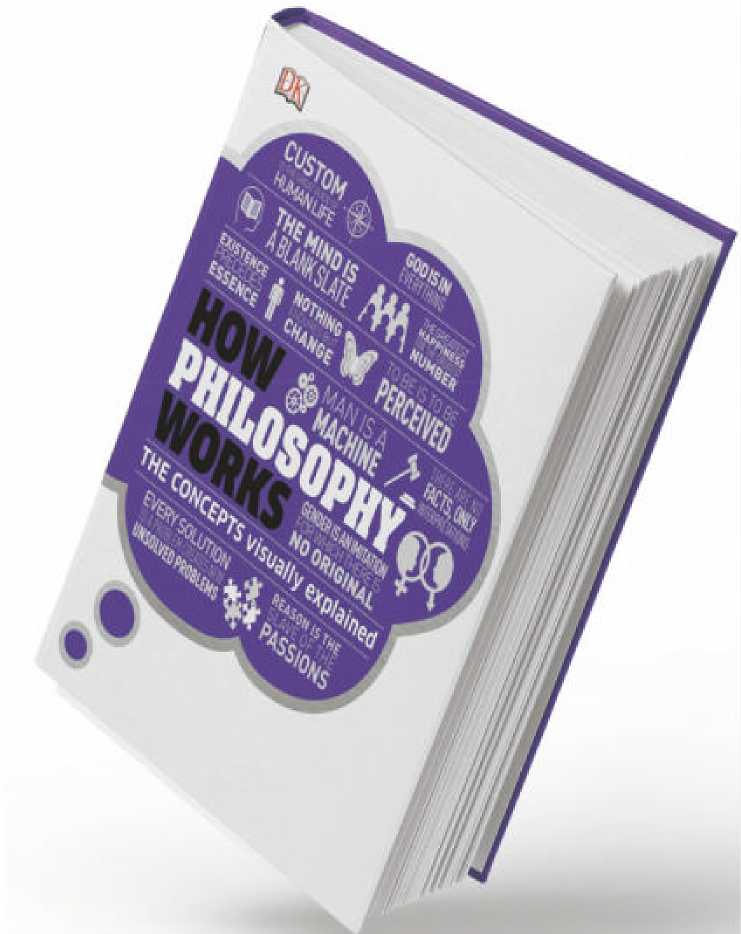
Containing the podcast team's trademark melding of insight and comedy, this makes the transfer from audio to page seamlessly. Some of the humour might be a bit risqué for the very youngest readers, but for everyone else this will be great fun, ideal to pick up and absorb in bite-sized chunks. Plus it might make a welcome change from buying the *Guinness Book of World Records* every year…

★★★★★

How Philosophy Works

Is this a book, or isn't it?

- Author: **Various**
- Publisher: **DK**
- Price: **£16.99 / $22**
- Release: **Out now**



This probably isn't the best question to pose to an actual philosopher – you'd be effectively asking for an earache. Still, that won't stop people from questioning the nature of the world around us, which means it's a good thing to have this book on hand to attempt to make what can seem a rather intimidating subject more accessible.

Beginning with an explanation of the foundations of philosophy before moving onto such topics as analytic philosophy, right and wrong and logic, the team at Dorling Kindersley sheds light on the subject matter in their own evocative way: via the use of snappy sentences and eye-catching images to explain things in the clearest possibly way.

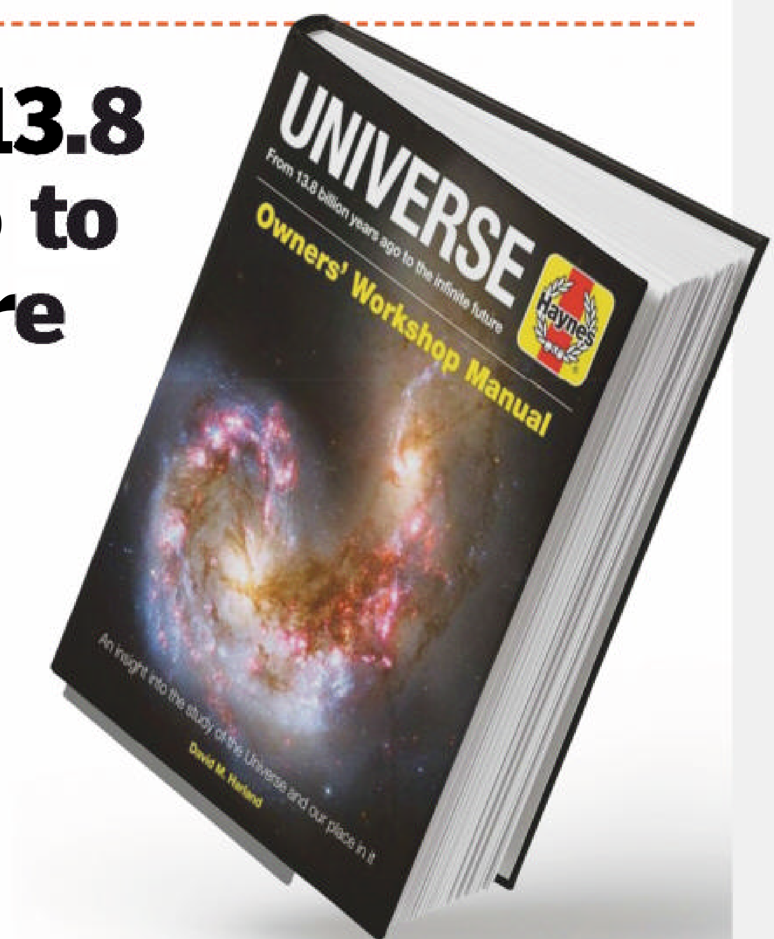
All of this is given credence by a team of eminent experts in the field. It's a lot to take in, especially for younger readers, but that's no reason not to give this a go.

★★★★☆

Universe: From 13.8 billion years ago to the infinite future

A brief history of time

- Author: **David M Harland**
- Publisher: **Haynes**
- Price: **£22.99 / $29.95**
- Release: **Out now**



By now you'll likely know what to expect from a Haynes manual, and you get that here in this latest edition, which rather ambitiously looks to chart the history of pretty much everything in existence. Full marks for ambition already.

Starting with ponderings on the nature of the universe and the rules that govern it from the likes of Isaac Newton, Edmund Halley and Johannes Kepler and spinning all the way through to the most recent space-bound discoveries, such as dark matter and a sighting of the oldest star found to date, those with even a passing interest in the universe and its workings won't be able to tear their eyes away from this. It's a great marker for how far we've come, and how much further we could go.

As is the norm with a Haynes manual, there's a lot to get through, and you'll certainly get your money's worth. Some of the publisher's books can be a bit niche, but the universal appeal of this book ensures that it stays a level above some previous instalments. In other words, we give you the go-ahead to add this to your no doubt already groaning book shelf. ★★★★★

Colossus: The World's Most Amazing Feats of Engineering

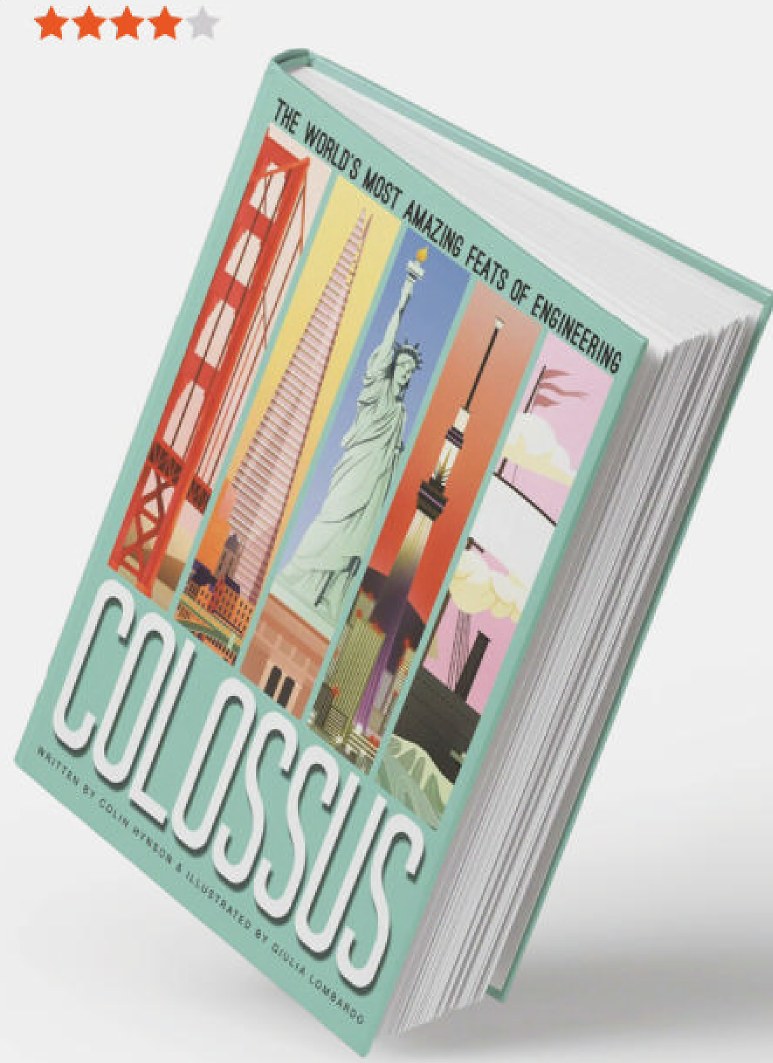
Brilliant buildings

- Authors: **Colin Hynson, Giulia Lombardo**
- Publisher: **Templar**
- Price: **£16.99 (approx $20)**
- Release: **Out now**

Whether it's a statue, tunnel, skyscraper, railway or monument, this is littered with examples of human ingenuity in the field of construction. It's not just a picture book, however. Popular children's book writer Colin Hynson provides handy annotations to Giulia Lombardo's sumptuous artwork, assigning plentiful food for thought when considering the Statue of Liberty or the Tokyo Skytree. If you think you know the stories behind these superstructures then think again – a surprisingly large amount of ground is covered.

This might not qualify for the 'not just for kids' category, but it definitely falls into the 'one you'll probably borrow from them from time to time' one.

★★★★☆



BRAIN GYM

GIVE YOUR BRAIN A PUZZLE WORKOUT

Wordsearch

S	A	P	E	N	E	T	E	L	E	P	O	R	T	O
N	P	A	N	G	O	L	I	N	Z	R	C	I	B	E
E	D	S	Z	Y	L	O	G	I	U	E	R	O	C	I
A	T	R	Q	X	Y	F	E	H	L	M	I	R	W	Q
N	C	W	U	T	M	W	C	E	H	A	E	U	R	M
D	A	N	A	V	P	C	I	Q	L	G	J	T	E	O
E	X	Q	N	J	U	T	E	P	N	K	L	R	I	P
R	F	Y	T	C	S	X	O	I	N	B	E	F	C	R
T	G	P	U	M	D	P	D	W	L	D	M	T	A	E
H	R	H	M	Q	E	O	B	Z	Q	L	R	A	L	M
A	Y	E	U	P	R	F	C	M	E	F	E	B	G	N
L	X	I	L	H	W	E	L	N	B	I	O	P	C	O
E	B	R	C	K	E	V	A	W	O	R	C	I	M	T
M	Z	S	D	T	U	N	W	E	D	I	A	V	M	E
A	K	I	L	O	M	E	T	R	E	M	I	L	R	J

FIND THE FOLLOWING WORDS...

QUANTUM
IBM
MICROWAVE
PANGOLIN
GLACIER
JET
CORE
SCHRODINGER
TELEPORT
NEANDERTHAL
OLYMPUS
KILOMETRE

Quickfire questions

Q1 When was the first supercomputer built?

- 1894
- 1924
- 1964
- 1984

Q2 How thick is an adult rhino's skin?

- 0.5cm
- 1cm
- 5cm
- 10cm

Q3 What metal alloy is the Earth's core mostly made of?

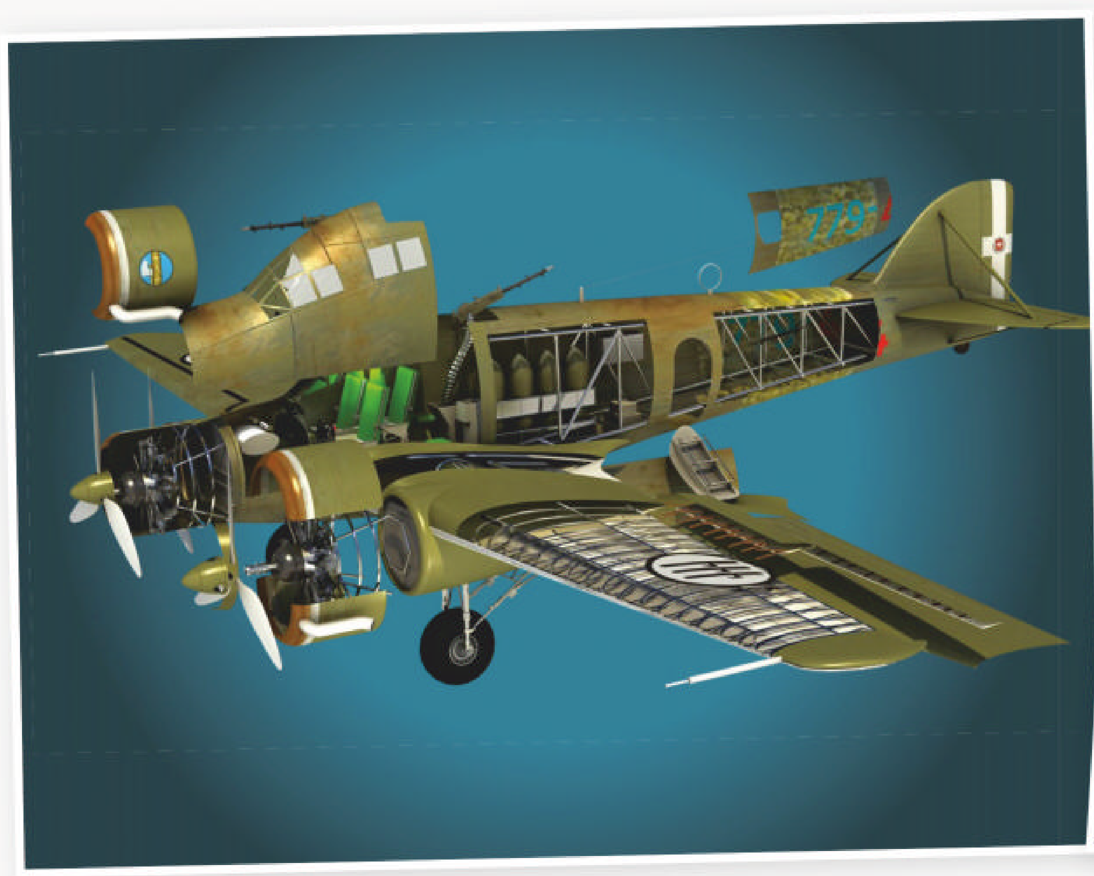
- Bronze
- Iron-nickel
- Meteoric iron
- Cupronickel

Q4 How long ago did humans evolve from our ancestors?

- 2,000 years
- 350,000 years
- 2.5 million years
- 10 million years

Spot the difference

See if you can find all six changes we've made to the image on the right



Sudoku

Complete the grid so that each row, column and 3x3 box contain the numbers 1 to 9

EASY

	6	8		3		5	4	
	1	9	5	8				
	4			9			7	
4			3	7	8			
1	5		9		6		8	
8		7	1	2	5	9		
5			4		7	6		8
9				6	3	4		
	8			5	9	1		

DIFFICULT

	2		5					
							1	
			6				8	4
	6	7				2		1
3		9	2	4		7	6	
		8						
				8	3			
	7			1				
6	4		7		2		9	

What is it?

Hint: It's massive, old, cold and takes ages to move anywhere.

A ....

Source: Wiki/Diego Delso

Spot the difference

Check your answers

Find the solutions to last issue's puzzle pages

Quickfire questions

Q1 Mercury

Q2 Coelacanth

Q3 Beelzebub

Q4 130kph

© NASA

What was it?

Space Shuttle

Get in touch
Send your ideas to…
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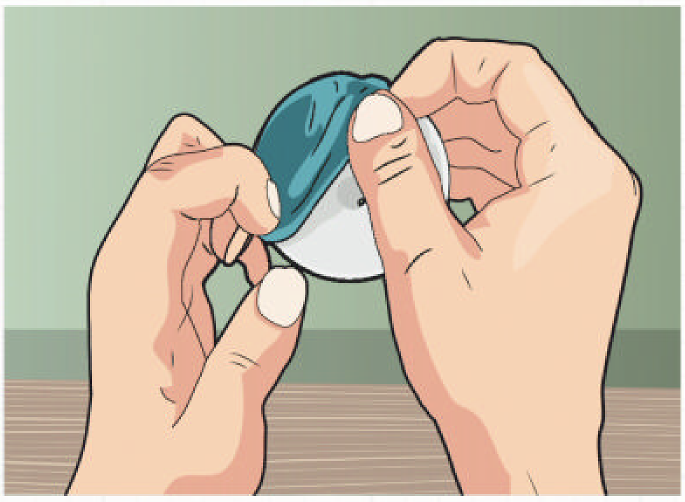
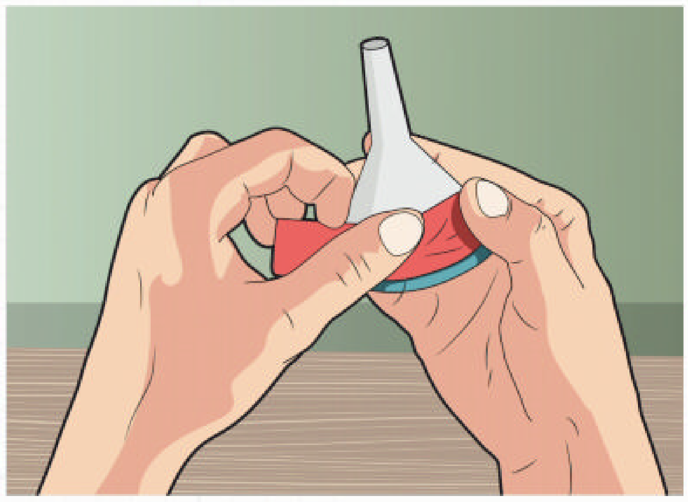
Make your own stethoscope

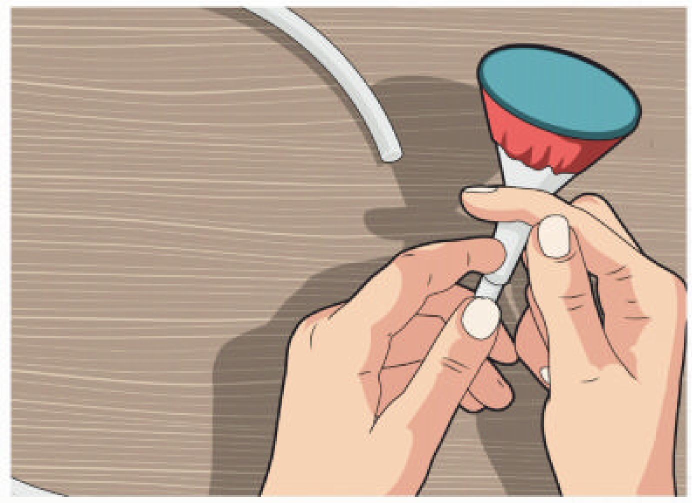
Hear anyone's heartbeat with this DIY stethoscope that uses tubing and funnels



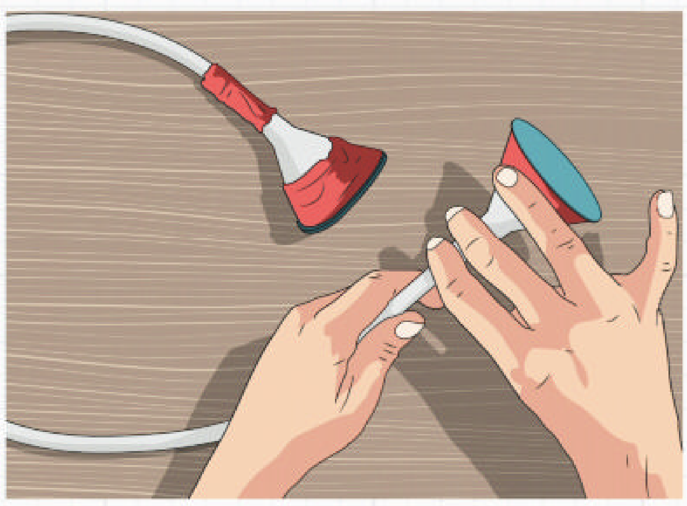
1 Stretch a balloon
First, cut off around one-third of a balloon from the open end, and stretch the rest of it over a small funnel. If you don't have a balloon, you can also use plastic wrap.



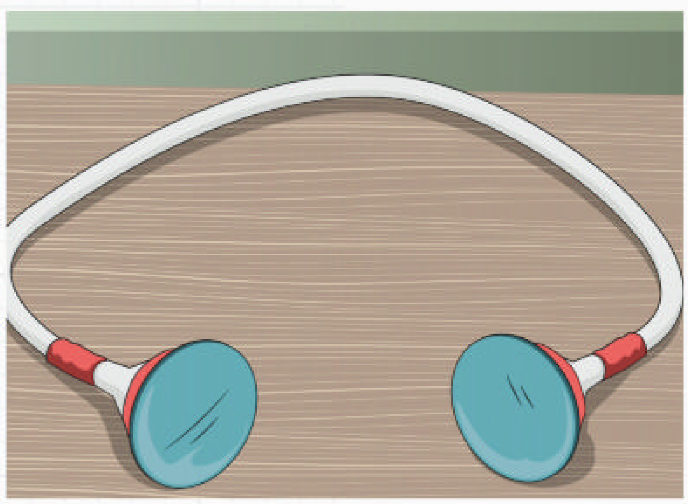
2 Secure it in place
Use some strong tape to secure the covering in place – the more secure your covering, the more effectively it will transfer the vibrations of a heartbeat into a sound you can hear.



3 Add some tubing
Cut a 40-centimetre length of clear, plastic tubing – you can get it in a hardware or garden supply shop. Push the narrow end of the funnel into the tube, and secure it tightly.



4 Add another funnel
Add another funnel at the other end of the tube. You don't have to cover this end with another balloon, but you can if you like. Why not try it without, then add a covering if needed.



5 Make it secure
Use strong tape to fix the second funnel to the tube. Make it as airtight as possible – any big gaps might mean the vibrations from the heartbeat are weakened slightly, and harder to hear.

6 Test it out
Put the covered end of the stethoscope over your heart and the other end over your ear. What can you hear? Try it on other people, and on different parts of your body, like your neck.

7 Record your heart rate
If you have a stopwatch, you can record your heart rate. Start the stopwatch and start counting the number of beats in 60 seconds. Try running around for a minute and do it again.

NEXT ISSUE
Make a particle detecting cloud chamber

SUMMARY…
As your heart pumps blood around your body, valves in the heart open and close. These valves cause vibrations that a stethoscope can detect. They cause the membrane – the balloon – to vibrate, which causes vibrations in the air inside the stethoscope. These vibrations travel down the air in the tube and your ear picks them up. As you exercise, the heart beats faster to transfer more blood around your body.

"Try it on other people, and on different parts of your body"

Had a go? Let us know!
If you've tried out any of our experiments – or conducted some of your own – then let us know! Share your photos or videos with us on social media.

INBOX
Speak your mind...

Get in touch
If you have any questions or comments for us, send them to:

How It Works magazine @HowItWorksmag howitworks@futurenet.com


Concrete roads are often noisier than asphalt

© Getty

Motorway making
Dear **HIW,**
I was driving along the M53 near Chester with my daughter. This particular part of the motorway was opened in 1972 with a concrete road.
We realised that there are very few road repairs on this motorway and wondered what the 'fail' rate is of concrete compared to tarmac?
We love your magazine so please keep up the good work!
Roy Balmer

Roads have undergone many trials and changes over time, but today the two main materials used for our motorways are concrete and asphalt. Asphalt is a surface that looks almost identical to tarmac, but is much more hard-wearing.

As you have noticed in your travels, concrete roads have a longer life span and are stronger. Because of this, they need repairing a lot less than the asphalt. As well as their strength, motorways made of concrete are less affected by oil leaks. Asphalt tends to damage more easily in accidental spills. Usually concrete roads last for around 40 years before being replaced, while asphalt lasts a quarter of this time. Today, asphalt roads are generally laid because they're cheaper and a safer surface, reducing skids. And while they need to be repaired more often than concrete, this material is more easily repaired.

Letter of the month
Jelly mystery
Dear **HIW,**
At a friend's for lunch the other day, we were served this very nice pudding – chocolate mousse, jelly and berries.
Both of these were made at the same time, chocolate mousse at the bottom and jelly on top. As it set, the one on the left swapped over and the jelly, but not fruit, moved to the bottom. This happened with all the straight glasses. They didn't mix together. How and why could this have happened?
Jacob (aged 13)


© Jacob

Jacob noticed that in glasses shaped like the one on the left, the jelly set below the mousse

To understand the science of jelly, we first need to think about how jelly sets. Jelly is often made with gelatin, which contains long protein molecules. As the jelly cools in the fridge, the molecules in the jelly will begin to tangle, trapping the water inside to solidify.

When the jelly begins to set, the interlinked three-dimensional protein structures begin to form in the highly dense gelatin. This causes it to move to the bottom of the glass. The light, airy mousse settles above, as it has a much lower density. The same can be said for the fruit. If there was no mousse, you would probably have found that the fruit all floats at the top of the jelly because the denser jelly mix sinks below.

In the case of your jelly-pudding combo, the shape of the glasses will have had an impact on where the jelly set. As the jelly and mousse are in complete layers, the whole body of jelly would need to move below the mousse to swap layers before fully setting. In the glass with a thinner base, there isn't the space for the jelly layer to move below in a smooth motion.

The curved edge of the glass on the right means that the surface area at the bottom of the jelly layer is significantly smaller than the top of the jelly layer. As the jelly tried to move layers, the slower process meant it couldn't reposition in time. It set before displacing the mousse, becoming a solid interlinked protein structure – unable to move further. Either way, both outcomes have created two delicious-looking varieties!

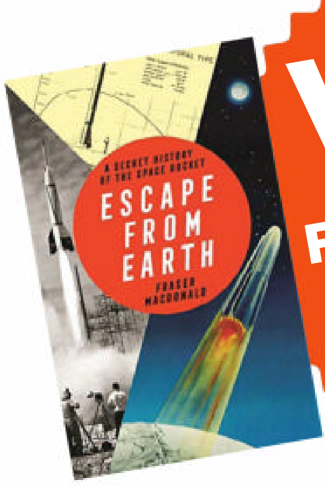

© Getty

Pregnant women are advised to sleep on their left side to help blood flow

Tossing and turning
Dear **HIW,**
I naturally turn over when I am sleeping. Apart from comfort, is this necessary to give the brain a good rest? And is it bad for the brain if I have a broken arm, and can't lie on one side?
Stephen Conn

The main reason we swap sleeping positions throughout the night is to do with comfort. However, studies have shown certain sleeping positions to benefit our health and wellbeing more than others.

Side sleeping is the most common position. It's thought to prevent snoring and may clear brain waste more efficiently during sleep. However, some studies say that lying on our left side could have more advantages for our bodies. Due to the position of our organs, this side is thought to improve digestion and heartburn, better drain toxins from lymph nodes and benefit circulation. Switching sides does help to relieve the constant pressure on certain organs and prevent numbness from leaning on limbs.



WIN!
ESCAPE FROM EARTH
Full of explosive revelations, *Escape from Earth* turns the familiar story of the Space Race upside down

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NEXT ISSUE... Issue 134 on sale **23 JAN 2020**

Space fires

Dear **HIW,**

Could you tell me what would happen if we were to light a fire in space?

Laila Jones (aged 10)

Your wish to understand how fire propagates in space is one also shared with NASA. The space agency has conducted hundreds of tests to see how fire behaves in this low-gravity zone.

When you light a fire on Earth, heated gas rises up from the flames, bringing in oxygen to fuel it. In space this rising action can't happen without the same gravitational pull, so a different method is used.

Molecular diffusion is the name given to the process that draws oxygen to the flame in space. Without gravity, hot air expands outwards rather than upwards. Oxygen molecules move towards the flame to replace lost oxygen and allow the fire to continue burning.

This happens 100 times slower than it does on our planet. Space fires can burn at lower temperatures and don't need as much oxygen. Lighting a fire in space is one thing, but to put it out is more difficult, so more concentrated fire extinguishers – such as the CO_2 they use on the International Space Station – are needed to extinguish the blaze. This is because more heat and oxygen needs to be removed in space for a fire to stop.

Flames in space don't hold the same teardrop shape, as air isn't travelling upwards

What's happening on... social media?

This month we asked you what piece of *Star Wars* technology you would bring into the real world

@AruneshV
"I'd like to bring in C-3PO so that there are no language barriers in communication, and this in turn serves as a unifying bond among the people around the world…"

@kittenbiiits
"Carbonite freezing could be utilised to cryogenically freeze people until cures for illnesses became available, or just as a one-way ticket to the future!"

@Truey59
"Lightspeed, we could get to the nearest star in a couple of years instead of the thousands it would take now."

@vpekic
"The 'head-bumping stormtrooper's' helmet in Star Wars: Episode IV A New Hope *that blocked him from seeing the door frame in front. I'd show it to my kids as a lesson that 'design is never done', not even in* Star Wars.*"*

Penguin life

Dear **HIW,**

Do penguins spend more time in water or on land?

Imagine being able to live both on land and in the oceans! Which would you prefer?

For penguins, they generally spend half of their lives each way. This being said, there are nearly 20 penguin species with different behaviour patterns. Some species spend up to 75 per cent of their time in the water. Fiordland crested penguins sometimes grow barnacles on their tails because they spend such long periods of time in the sea, about 60 to 80 days at a time.

Penguins' feathers are tightly packed for waterproofing

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FAST FACTS

Amazing trivia to blow your mind

400KM

A POCKET LASER POINTER POINTED UP FROM EARTH CAN BE SEEN FROM THE INTERNATIONAL SPACE STATION

2028

IN A FEW YEARS, QUANTUM COMPUTERS WILL CREATE AI THAT CAN DO ANYTHING WE CAN DO

$300,000

DESIGNING AND DEVELOPING A FULL-SIZE CONCEPT CAR IS VERY EXPENSIVE

800 METRES

WIND AT HIGHER ALTITUDES CAN GENERATE FOUR TIMES THE POWER OF GROUND-BASED WIND TURBINES

1931

THE TERM 'TELEPORTATION' WAS FIRST USED NEARLY A CENTURY AGO BY WRITER CHARLES FORT

CROCODILES CAN 'FEEL' THEIR PREY SWIMMING WITH THEIR PRESSURE-SENSITIVE SKIN

THE ANTIKYTHERA MECHANISM IS AN ANCIENT COMPUTER MADE BY THE GREEKS OVER 2,000 YEARS AGO

1,000,000 YEARS

SOME GLACIER ICE IN ANTARCTICA HAS EXISTED SINCE LONG BEFORE HUMANS EMERGED

5 METRES

THE MAXIMUM CURRENT ACHIEVABLE DISTANCE FOR INDUCTIVE (WIRELESS) POWER TRANSFER

SCIENTISTS HAVE BEEN DRILLING CORES OUT OF THE SEA FLOOR SINCE THE 1968 DEEP-SEA DRILLING PROJECT

-93 CELSIUS

MERCURY'S POLAR REGIONS CONSTANTLY ENDURE TEMPERATURES LOWER THAN ANYTHING RECORDED ON EARTH'S SURFACE

IN QUANTUM PHYSICS, THE TINIER A PARTICLE IS, THE MORE LIKELY IT IS TO BE IN SEVERAL PLACES AT ONCE

AIRFIX

STARTER SETS: WHAT'S ON THE BOX?

Every Airfix Starter Set box contains a wealth of information to help you choose the best kit and achieve the best finish.

1. History
A small piece of history is included on the top of each Airfix kit box. This gives some background information of the product, including actions the real item was involved in. The area also shows the dimensions of the finished model and the number of pieces.

2. Flying hours
Become a member of the Airfix Club and you can collect the Flying Hours to receive FREE model kits. The bigger the kit, the more Flying Hours are available to accumulate.

3. Skill level
The skill level, from 1 to 4, explains how difficult the model will be. A higher skill level kit often has more parts and is more challenging to build.

4. Paints, Cement and brushs
Everyting to build a finished model is included, including model cement, paint brushes and acrylic paints. The Humbrol™ products will enable you to create the best finish for your model.

5. Scheme
The scheme is outlined on the top of the box with the markings and descriptions.

6. Decals
The side profile on the front shows the position of the decals to give you a clear idea what the final model will look like.

7. Product code
The product code is unique to each kit. It helps you to identify your kit of choice easily, assists with navigating through the catalogue or Airfix website accurately, determines the size of the kit and gives guidance to the number of parts.

8. Model scales
The scale of the kit indicates how large the model will be in relation to the full size vehicle. All of the aviation Starter Sets are 1:72 scale, therefore the model is 72x smaller than the original (1:32 = 32x smaller). The smaller the scale number – e.g. 1:24 = the larger the kit compared to the original. All of the automotive Starter Sets are 1:32 and the tanks are 1:76.

Airfix.com
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